NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

HASTILY FORMED NETWORKS—CHAOS TO RECOVERY

by

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September 2015

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704–0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 2015	Master's Thesis

4. TITLE AND SUBTITLE
HASTILY FORMED NETWORKS—CHAOS TO RECOVERY

5. FUNDING NUMBERS

6. AUTHOR(S) Arezzi, Mark

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB protocol number ____N/A____.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE
A

13. ABSTRACT (maximum 200 words)

Historically, response to catastrophic events has failed to reestablish communications rapidly, resulting in an extension of the chaotic response phase. Communication is not simply a support service but an independent strategic imperative within the crisis response system. Current domestic crisis management acknowledges that a communications system is indispensable yet continues to prioritize and utilize communications as a support function. This thesis considers the centrality of the communications system binding complex emerging systems.

The goal for crisis response is also to stabilize disrupted and interrelated systems that define a modern society. A communications system is the key element that allows systems to self-organize, adapt, and exert control over the chaos. Defining the role of communications requires an understanding of complexity, chaos, systems, and network evolution. There is a need to change crisis response organizations to reflect a modern understanding of the changing technical environment, and the foundational function communications serves in linking dynamic complex systems. This thesis also identifies the forces unleashed in the aftermath of a catastrophic event and illustrates how the rapid restoration of communications is required for successful crisis response.

14. SUBJECT TERMS
disaster, catastrophe, complexity, chaos, systems, convergence, emergence, network theory, hastily formed network, Hurricane Katrina, Haiti, information and communication technology (ICT), social network analysis, incident command system, Federal Emergency Management Agency (FEMA)

15. NUMBER OF PAGES
221

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UU

NSN 7540–01-280-5500
Standard Form 298 (Rev. 2–89)
Prescribed by ANSI Std. 239–18

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HASTILY FORMED NETWORKS—CHAOS TO RECOVERY

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Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF ARTS IN SECURITY STUDIES
(HOMELAND SECURITY AND DEFENSE)**

from the

**NAVAL POSTGRADUATE SCHOOL
September 2015**

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ABSTRACT

Historically, response to catastrophic events has failed to reestablish communications rapidly, resulting in an extension of the chaotic response phase. Communication is not simply a support service but an independent strategic imperative within the crisis response system. Current domestic crisis management acknowledges that a communications system is indispensable yet continues to prioritize and utilize communications as a support function. This thesis considers the centrality of the communications system binding complex emerging systems.

The goal for crisis response is also to stabilize disrupted and interrelated systems that define a modern society. A communications system is the key element that allows systems to self-organize, adapt, and exert control over the chaos. Defining the role of communications requires an understanding of complexity, chaos, systems, and network evolution. There is a need to change crisis response organizations to reflect a modern understanding of the changing technical environment, and the foundational function communications serves in linking dynamic complex systems. This thesis also identifies the forces unleashed in the aftermath of a catastrophic event and illustrates how the rapid restoration of communications is required for successful crisis response.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAP	after action report
API	Application Programming Interfaces
APAN	All Partners Access Network
CANA	Caribbean News Online
CIA	Catastrophic Incident Annex
CERT	Community Response Teams
COML	communications unit leader
COP	common operating picture
DART	Disaster Assistance Response Team
DEC	disaster emergency communications
DHS	Department of Homeland Security
DMAT	disaster medical assistance teams
DMORT	disaster mortuary teams
DOD	Department of Defense
EOC	Emergency Operations Center
ESF	Emergency Function Annex
ETC	Emergency Telecommunication Cluster
FCO	federal coordinating officer
FEMA	Federal Emergency Management Agency
FITTEST	Fast IT and Telecommunication Emergency and Support Team
HA/DR	humanitarian assistance and disaster relief
HFN	hastily formed networks
HSPD	Homeland Security Presidential Directive
IAP	incident action plan
IASC	Inter-Agency Standing Committee
IC	incident commander
ICS	Incident Command System
ICT	information and communications technologies

IMAT	incident management assessment teams
IP	Internet Protocol
IRC	International Red Cross
JFMCC	Joint Forces Maritime Component Command
JTF	joint task force
MEMA	Mississippi Emergency Management Agency
MERS	Mobile Emergency Response Support
NAVO	Naval Oceanography Center
NLE	national level exercise
NGO	nongovernmental organizations
NIMS	National Incident Management System
NPS	Naval Postgraduate School
NRF	National Response Framework
NRP	National Response Plan
NECP	National Emergency Communications Plan
OASD-NII	Office of the Assistant Secretary of Defense/Networks and Information Integration
OCHA	Office for the Coordination of Humanitarian Affairs
PAHO	Pan American Health Organization
PFO	principal field officer
PoLO	pockets of local order
RECCWG	Regional Emergency Communication Coordination Working Group
RTAT	rapid telecommunications and technology teams
SA	situational awareness
SATCOM	satellite communications
SME	subject matter experts
SNA	social network analysis
UN	United Nations
UNICEF	UN Children's Rights and Emergency Relief Organization
UNWASH	UN Water, Sanitation and Hygiene Cluster

U.S.	United States
USAID	United States Agency for International Development
V&TC	Volunteer and Technical Community
WFP	World Food Programme
WiFi	wireless fidelity
WiMAX	wireless microwave access

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EXECUTIVE SUMMARY

Modern society is a complex system dependent on a multitude of interrelated sub-systems. A catastrophic event disrupts and disconnects the socio-technical systems that bind society. This disruption unleashes a massive complex response, which requires the rapid restoration of communications in order to return stability. Historically, crisis response has consistently lacked a comprehensive communications strategy. An effective communications strategy must: (i) address complexity; (ii) identify the role communications serves as a mechanism to control chaos; (iii) foster self-organization; (iv) integrate the social forces that emerge and converge during a catastrophic event; and (v) manage network evolution and the expected deluge of data.

A disrupted social state is a system in chaos. The catastrophic event also creates cascading disruptions to the interrelated systems that make up a modern society. Chaos implies a widely bounded nonlinearity within a system; relationships within the social systems are dynamic and disproportionate. This thesis identifies how a catastrophic event is a disruption of the social system. The goal of crisis response is to control the chaotic state and return the social system to stability. Response forces can utilize two methods to control chaotic states: perturbations and alteration of orbits. Perturbation uses the sensitivity of chaotic states to small changes that create nonlinear results.[1] Altering orbits is a method that is used to control chaos by carefully identifying changes in a system to identify attractors.[2] Both these methods are heavily reliant on communications and application of complex systems sciences.

The use of small information and communications technology (ICT) teams is an example of controlling chaos through perturbations. The teams are responsible for ICT reconnaissance, delivering trusted situational data and quickly starting the process of

[1] L. Douglas Kiel, *Managing Chaos and Complexity in Government: A New Paradigm for Managing Change, Innovation and Organizational Renewal* (San Francisco: Jossey-Bass Klein, 1994).

[2] William L Ditto, and Louis M. Pecora, "Mastering Chaos," *Scientific American* 269, no. 2 (August 1993): 78–84; L. Douglas Kiel, "Chaos Theory and Disaster Response Management: Lessons for Managing Periods of Extreme Instability," in *What Disaster Response Management Can Learn from Chaos Theory, California Emergency Medical Services Authority–Conference Proceeding*, ed. Gus Koehler, May 1995, https://www.library.ca.gov/CRB/96/05/over_12.html

implementing a communications network. Peter Denning[3] of the Naval Postgraduate School, developed the concept of hastily formed networks (HFN). These concepts utilize a systems approach to restore communications rapidly in the immediate aftermath of a catastrophic event. The concept acknowledges that the communications system relies on technical and social systems. The emphasis is an independent effort that applies advanced technology to link the affected communities and assist the converging response efforts. The Naval Postgraduate School's Hastily Formed Network Group has deployed and field-tested these concepts with success. The experiences from these deployments led Brian Steckler (the director of this group) to propose the creation of rapid technology assessment teams (RTAT). Similar teams were used effectively (albeit unofficially) by Federal Emergency Management Agency (FEMA) during Hurricane Sandy.[4] These teams are the perturbations necessary to begin the process of reestablishing a network.

Small ICT teams start the process of linking the isolated communities, creating and expanding network connectivity. According to network theory, this rapidly created and growing network will naturally create hubs as it evolves. Hubs are actors that have the greatest number of links within a network. The case study analysis presented in this thesis demonstrates that the response networks grow and follow the principles of network theory. However, a common problem is that the networks are highly fragmented, and there is little successful engagement of the affected communities and emergent groups. The data strongly suggests that network evolution is not currently well-managed and that this process is shaped significantly by an organization's ICT capabilities. By restoring connectivity the resulting network must be carefully managed, or the result will continue to be structurally unsound networks that are unable to successfully share information or coordinate activity.

Formation of hubs is a method of controlling chaos through alteration of orbits. The hubs serve as both geographical and virtual basins of attraction during the response phase. Geographical hubs are natural centers for organizing and require support of greater

[3] Peter J. Denning, "Hastily Formed Networks," *Communications of the ACM* 49, no. 4 (2006): 15–20.

[4] Sean C. Kielty, and John MacLean, "We Know You Can Hear Us: The Model Emergency Communications Response to Super Storm Sandy" (unpublished, Federal Emergency Management Agency, 2014).

access to connectivity and overall network management. The formation of these hubs as basins of attraction serves to differentiate events into smaller manageable events. These geographic hubs within the affected zones promote pocket of local order.[5] Virtual hubs are the portals by which converging organizations operate outside the affected zone. These portals can connect utilizing undamaged access to advanced information and communications technology.

Catastrophe releases massive emergent and convergent social forces. The emergent forces respond from within the affected population. The convergent forces are the external response to the event. Emergent forces are constantly at work within every active system. In a disordered social system, emergence is the resulting complex behavior and relationships of individuals and groups. The disorder creates an urgent, powerful, and naturally occurring (emergent) impulse to self-organize. This naturally occurring phenomenon is an integral part of complex systems. The affected communities in a catastrophe are part of a complex social system that will self-organize. The limits to this drive to self-organize are communications. Without access to ICT, the organization would be reduced to the span of the spoken word. These emergent groups would be isolated and unable to coordinate crisis response effectively. The emergent groups represent a massive potential within crisis response and have historically been the most effective force in a successful response. The national response has acknowledged in the *National Response Framework* (NRF)[6] that successful crisis response requires the effort of the "whole community."

Convergent forces are the social system's response from outside the affected regions (i.e., the organized governmental or international agencies, efforts by private industry and volunteer groups). The convergent forces are the labor, resources, and information from outside directed toward the affected regions. The convergent forces are

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[5] Eva Törnqvist, Johan Sigholm, and Simin Nadjm-Tehrani, "Hastily Formed Networks for Disaster Response: Technical Heterogeneity and Virtual Pockets of Local Order," in *Proceedings of the 6th International ISCRAM Conference*, ed. Jonas Landgren, Urban Nulden, and Bartel Van de Walle, May 2009, http://www.iscramlive.org/ISCRAM2009/papers/Contributions/228_Technical%20and%20Cultural%20Heterogeneity%20in%20Hastily_Sigholm2009.pdf

[6] U.S. Department of Homeland Security, *National Response Framework* (Washington, DC: U.S. Department of Homeland Security, 2013), http://www.fema.gov/national-preparedness-resource-library

in the best position to effect rapid restoration of communications with resources, trained personnel, and organized response.

The goal of crisis response is to restore order quickly to the socio-technical systems to decrease human suffering and to limit economic loss. The most crucial component is the rapid restoration of a communications system that integrates those emergent and convergent forces.

An early intervention to restore communications must address the concept that a communications system is a complex system that is the foundation for social self-organization. This intervention is a primary strategic objective. Communications systems must address both the technical and social systems that have been disrupted. It is vital to understand that this is a system of systems. Catastrophes severe the links that bind the social systems and the technical systems. The most effective way to reestablish stability and promote recovery is to rebuild the links, understand the dynamics of network growth and behavior and prepare to manage the avalanche of inflowing data.

Catastrophic events are fortunately rare, which limits the data sets. The two case studies illustrate how the U.S. and the United Nations each have responded to a catastrophe and the consequences of the failure to implement a comprehensive communications strategy. The case studies were selected based on environmental factors and access to modern ICT. The contrasting organizational management and the consistent failure to rapidly restore a communications system indicate an underlying problem applying ICT in modern crisis response. The NPS HFN group responded to both events and demonstrated that a small, technically adept team in an extreme environment can rapidly restore communications. The data from these two events illustrate common problems. The crisis response forces fail to link the affected communities quickly and also fail to create a functional communications system. The connection of the emergent and convergent forces using advanced ICT is the first step to creating a communications system.

In the U.S., the current crisis response management and organizational model is described in the *National Response Framework* (NRF)[7] and the *National Incident Management System* (NIMS).[8] NIMS is the Department of Homeland Security (DHS) organizational and management guide that governs the participation of all levels of government, nongovernmental organizations, and private sector entities for all hazard events. Incident Command System (ICS) is the basis for organizing. ICS is a hierarchical command network model designed in the 1970s by firefighters in California. This system has not been significantly updated or reorganized in its 40 years of service even though the world has experienced a technical revolution that has created far greater interconnection and complexity. Currently, NIMS and ICS communications and information management support operations, planning, logistical, and administrative concerns. The communications and information efforts are fragmented and spread out within NRF and ICS organization. This implementation of communications does not reflect holistic systems approach. A review of the response literature has found that:

- Communications do not have a leadership role within the ICS command structure (with the exception of the public information officer).
- Communication efforts are fragmented.
- Communications strategy requires strategic objectives that are independent of other response goals.
- Rapid restoration of a communications system is not a primary strategic goal in the official response literature.
- The crisis response efforts continue to overlook this problem. For example, the National Level Exercise in 2011 largely ignored the role of communications.

Advances in technology have been key to the emerging scientific study of complexity. This research examines relationships among components of a system and how those relationships and interactions collectively behave. Social, communication, technology, infrastructure are all complex systems that exist in nonlinear environments. Any approach to a comprehensive communications strategy must be understood through

[7] Ibid.

[8] U.S. Department of Homeland Security, *National Incident Management System* (Washington, DC: Department of Homeland Security, 2008), accessed August 1, 2014, http://www.fema.gov/pdf/emergency/nims/NIMS_core.pdf

this lens. Society requires communications.[9] A catastrophic event disorders society and the social system. The ability to self-organize and restore order requires communications.

As the memories of Hurricane Katrina fade, the impetus for improvement in crisis response withers. The weakening resolve is a natural cycle with respect to policy-making. Currently, national response plans lack a coherent and comprehensive communications strategy. Divided responsibilities fragment communications efforts. Despite being highlighted in the *National Response Framework* (NRF),[10] the fundamental need for communications has not been incorporated in changes to the National Incident Management System (NIMS) or Incident Command System (ICS). Crisis management professionals must understand the central role of information and communications technology (ICT) and recognize the primary strategic objective of rapid restoration of a communications system. Mastery of these concepts is essential in order for crisis response to contain the initial chaos and to begin the process of recovery.

[9] Louise K. Comfort, "Self-Organization in Complex Systems," *Journal of Public Administration Research & Theory* 4, no. 3 (1994): 393–410; Niklas Luhmann, "Systemtheorie, Evolutionstheorie und Kommunikationstheorie [System Theory, Evolution Theory, and Communication Theory]," in: *Soziologische Aufklärung 2* [The Differentiation of Society], trans. Stephen Holmes and Charles (Opladen, Germany: Westdeutscher Verlag), 193–203.

[10] U.S. Department of Homeland Security, *National Response Framework*.

ACKNOWLEDGMENTS

First and foremost, I need to thank my wife, Jennifer, and my children, Luke and Justine, for unbelievable levels of support, endurance, and patience. Their encouragement is the foundational element of all I do.

I would also like to thank the Fire Department of New York and the Center for Terrorism and Disaster Preparedness for giving me this fantastic opportunity. A special acknowledgment goes to Sean Newman for his help and tireless understanding.

It is important that I acknowledge the Naval Postgraduate School and the faculty and staff of the Center for Homeland Defense and Security for the challenging and rewarding program. It was an honor to have been accepted and a relief to finish. To my cohort "1302," and especially George, Brian and Tim—it was the best of times.

My advisors were a source of inspiration and torment. Douglas and Brian, I thank you for all your work.

I must also acknowledge the special assistance I received from the following:

Sean Everton, thank you for spending your time and sharing your knowledge. It was generous and truly appreciated.

Louise Comfort of the University of Pittsburgh, your work was an essential component to all I wrote. Thank you for your kind words, good advice, and encouragement.

Grace Palladino, I can't begin to thank you for all your help editing and for actually reading my thesis.

Lastly, I'd like to dedicate this work to my brother, Michael. Till we meet again.

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I. INTRODUCTION

A. RESEARCH QUESTION

Catastrophic events create massive social, technical, and environmental disorder. These events are accompanied by cascading failures of critical infrastructure (particularly communications). The initial disaster response environment is chaos. Responses to catastrophes, such as Hurricane Katrina and the earthquake in Haiti, have demonstrated a widespread failure to address critical information and communication technology (ICT) needs. It is critical for the crisis response community to view ICT as a primary strategic objective that is both independent and interrelated with all facets of response. Any ICT solution must contemplate the problems holistically, that disruption of systems represents severing of the linkages that network a modern complex technical reliant society. The disruption is defined as chaos. In this chaos, social forces are forces released that emerge or converge. These forces represent the social response to a catastrophic event. The effectiveness is bounded by the communication linkage and information sharing systems. The overall goal is to control the chaos, the most effective means require effective communication. Furthermore, a satisfactory solution must also take into account the many ways chaos and complexity affect collaboration and cooperation. It must also consider that emergent and convergent forces require some mechanism to integrate them effectively. The goal is a rapidly distributed response focused on reestablishing network connectivity and creating functioning communications systems. These problems require new and innovative technical and social solutions.

What is the most central factor contributing to failures in catastrophic responses? How can the national crisis response be improved? These questions are profoundly broad. The contention of this thesis is that a primary objective of crisis response must be the rapid reestablishment of communications.

The systems and forces involved in crisis response revolve around chaos, complexity, self-organization, and emergence and convergence. Without communication,

chaos is extended at the expense of self-organization. Emergent and convergent forces must network or risk behaving in an isolated and uncoordinated manner.

How can communications be reestablished within the environment complex catastrophic crisis response? This thesis aims to answer these questions by (i) examining how communications systems are understood in crisis response systems and how failures in communication are common in crisis response; (ii) identifying the forces at work and the impact of communication failure; and (iii) proposing possible solutions for improving future response. It is essential to examine common needs and problems during the response stage of humanitarian assistance and disaster response (HA/DR). A catastrophic event is initially chaotic and entails massive complexity. There is a primal social need to create or restore social order from chaos; the most vital tool is communication. Without it, the chaotic phase would extend, and response would be uncoordinated.

B. PROBLEM STATEMENT

The loss of communication inhibits leadership from exerting command and control and also leaves responders with a murky common operating picture.[1] The response performance degrades resulting in an increase in humanitarian suffering and economic losses. At the same time, isolated communities cannot self-organize effectively or integrate with the responding forces. Past catastrophic events have demonstrated that the communications system is a vital component of an effective response; communication failure is almost certain to thwart a successful operation. The crisis response community must carefully address this problem, examine new processes, update response plans and organizational models, and adjust budgets while investigating technical solutions. This thesis considers the gap in communications during the response phase and examines solutions to address this elusive and critical problem. Ineffective response has a heavy cost in humanitarian and financial terms, and so there is a serious need to improve the communications response. Potential solutions will further the discussion of this essential component of disaster response.

[1] Lynn E. Davis, Jill Rough, Gary Cecchine, Agnes Gereben Schaefer, and Laurinda L. Zeman, *Hurricane Katrina Lessons for Army Planning and Operations* (Santa Monica: RAND Corporation, 2007), 38.

C. BENEFITS OF STUDY

This thesis examines the environmental and social challenges of crisis communications. The case study analysis compares common and unique problems within the context of a catastrophic event. Though the majority of this study is focused upon the subdivisions of the response phase of disaster management, the objective is to effect change in planning and organization. As Quarantelli states, this type of research should "provide a sense of how the world actually works."[2]

The objective of this study is to bridge the gap between academic research and disaster response practitioners. The aim is to fuse academic research with practitioner experience, and this research is pursued with future disasters in mind. The acceleration of the technical environment is a variable that presents both opportunity and obstacles for crisis response. Planning and management often react to past disasters to drive policy changes, but reaction does not account for rapid technical advances.[3] As the technical landscape changes, traditional response doctrines need to be challenged. The theme of the primacy of communications in crisis response will further the debate on the policies and organizational principals for future crisis management decisions. The ultimate goal is to improve crisis response by addressing this historically complex and difficult problem.

D. HYPOTHESIS

The data from historic crisis response demonstrates a continual failure to reestablish communication quickly. The continual failure either represents a reality that is unsolvable or some new solution needs to be pursued. In other words, communication will be restored in a methodical and gradual manner or that communications has not been properly understood in the context of complexity and chaos. The primary response management and organizational models do not make communications a primary strategic objective. Research demonstrates that crisis response planning has continually underestimated the essential nature or the resources required to reestablish

[2] Enrico L. Quarantelli, "Converting Disaster Scholarship into Effective Disaster Planning and Managing: Possibilities and Limitations," *International Journal of Mass Emergencies and Disasters* 11, no. 1 (1993): 21.

[3] Ibid., 31–35.

communications. The data points to a gap in response planning: a lack of a communications strategy. An effective communications strategy must: (i) address complexity; (ii) identify the role communications serve as a mechanism to control chaos; (iii) foster self-organization; (iv) integrate the social forces that emerge and converge during a catastrophic event; and (v) manage network evolution and the expected deluge of data.

The Naval Postgraduate School (NPS) Hastily Formed Networks (HFN) group is experimental information and communications technology (ICT) team that has deployed to the most extreme HA/DRs. These small teams have continually reestablished information and communications networks in the affected zones. The data from these deployments represents a model of how communications can be reestablished in extreme conditions. This model provides a practical and tested approach to rapid communications restoration.

Crisis response requires organizational change. Information and communications need to be an objective unto themselves. Currently, the role of communications in domestic response is support. Also currently, within the *National Response Framework* (NRF), communications and information management support operations, planning, logistical, and administrative concerns.[4] The communications and information efforts are fragmented and spread out within NRF and in Incident Management System (ICS) organization. Any change should aim to consolidate information and communications and provide sufficient leadership influence to pursue independent strategic objectives.

E. SCOPE

The objective of this thesis is to create the proper context to define the concepts and theories that describe the context and how they relate to primacy of communications in a complex catastrophic crisis response. Defining catastrophe requires a definition that sets clear boundaries. This definition is a source of vigorous debate in disaster research; however, a clear definition creates the canvas upon which the concepts and theories of

[4] U.S. Department of Homeland Security, *National Response Framework* (Washington, DC: U.S. Department of Homeland Security, 2013) http://www.fema.gov/national-preparedness-resource-library

chaos and complexity can be explored. For the purposes of this thesis, a catastrophe is defined as a massive disruption to the interconnected modern socio-technical systems. The links and relationships of these systems have been severed. Any formulation of a communication strategy requires an understanding of systems theory; the role communication plays in social self-organization and the manner emerging networks evolve.

The primary focus is domestic crisis response. The thesis assumes any catastrophic event will require assistance from the federal government. The objective of this thesis is to demonstrate the central role of communications and the gaps found in the *National Response Framework* (NRF).[5] The NRF represents the guide and organizational basis for national response to disasters and emergencies. The framework includes the National Incident Management System (NIMS), Incident Command System (ICS), and the supporting annexes.

This thesis uses data from two case studies: Hurricane Katrina and the earthquake in Haiti. The objective of this research is to demonstrate how communications were mishandled during Hurricane Katrina and how subsequent revisions have continued this mishandling. The earthquake in Haiti serves two purposes. First, it illustrates the affect communications failures have on crisis response, and second, the international crisis response system provides a management contrast with a common outcome. The earthquake in Haiti occurred five years after Katrina. This short span of time reveals the speed of change of the technical landscape and the new challenges for crisis response. The NPS HFN group responded to both events, and its deployments represent a demonstration of small technical teams successfully reestablishing local ICT links.

It is beyond the scope of this thesis to cover certain aspects of communications and crisis response, such as:

- public messaging
- media
- civilian-military

[5] Ibid.

- private-public partnerships
- volunteer and technical communities

The interaction of these essential components presents crisis responders with benefits, challenges, and obstacles that are beyond the scope of this paper. One can conclude that there is greater need to develop a comprehensive communications strategy for future crisis response. Greater interconnectivity, greater data flows, and greater complexity require increased effort to achieve a successful communication strategy.

II. LITERATURE REVIEW

This literature review assesses research and concepts that define the environment (catastrophic event); the concepts and theories that describe response behavior (chaos, complexity); how complex systems are interrelated; the social forces released (emergence and convergence); U.S. and United Nations (UN) response framework; and hastily formed networks. The environmental state of the problem requires a clear definition (see Figure 1). The environmental state of the problem requires a clear definition, and to that end, the literature review will consider several definitions for catastrophe. The goal of responders is a swift transition from the initial chaos to a more stable state. Communication is the foundational complex system that binds and integrates the interrelated systems. The loss of communication severely inhibits effective relief.

Complexity and systems are a central theme of this thesis. A catastrophic event releases powerful social forces. Emergent forces respond from within the affected communities, and convergent forces respond from the outside. The forces involved reflect the relationships of chaos and complex systems, the interdependence of emergent and convergent forces, and the role communication plays. The nature of a catastrophe must be understood to frame the relationships that the forces release. The concept that a catastrophic event is a social event compressed in social time defines the relationship to social, systems, and network theory to the processes of communication. During a catastrophe, communities are devastated, and the need for aid releases convergent and emergent forces that must be bound by technical and social networks. The literature examines communication systems during catastrophic events from the perspective of failures and the effect on the extended chaos of the response phase.

The responses to Hurricane Katrina and the earthquake in Haiti reflect two disaster management styles with different organizations that were operating in different periods of the technical revolution and with different approaches to implementing a communications strategy. They both failed. The common response shortcoming was the inability to establish effective communication. These failures point to a misunderstanding of communications and the role of information and communication technology. The

focus of this research is the response phase, but the recommendations need to be implemented long before the impact of a catastrophic event.

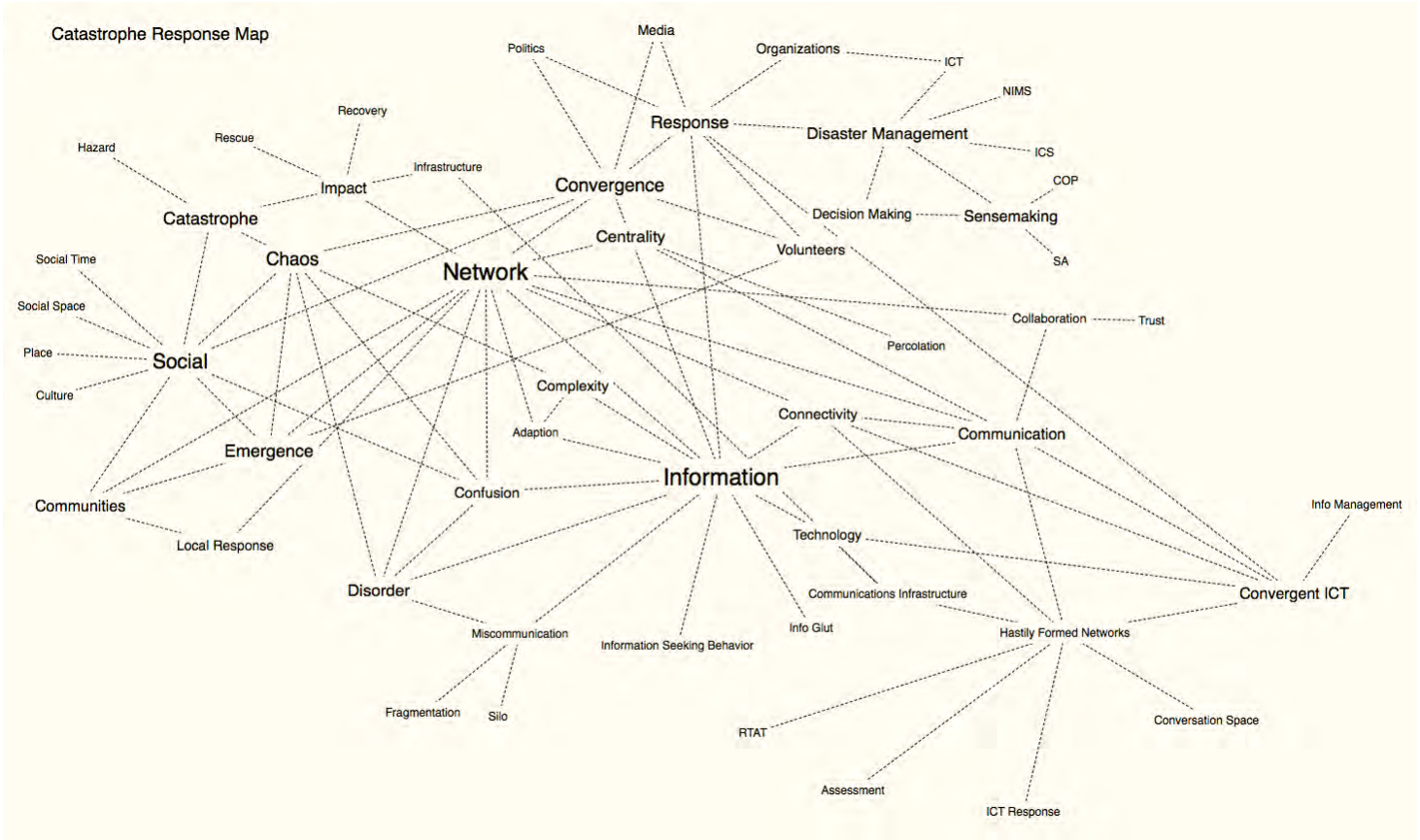

Figure 1. Towards a Root Definition of Catastrophe and Communications[16]

[16] Figure based on concept from: Denis Smith, "In the Eyes of the Beholder? Making Sense of the System(s) of Disaster," in, *What is a Disaster? New Answers to Old Questions*, ed. Ronald W. Perry, and Enrico L. Quarantelli (Philadelphia: Xlibris, 2005), 225.

A. DISASTERS AND CATASTROPHE

What is a disaster and why is it important to describe clearly? It would seem like a relatively easy word to define; however, it is crucial to understand the environment of the given disaster. The University of Delaware Disaster Research Center has led the effort to define this term not as a mechanism but as a social event. So why is terminology important: what is the concept? This is more than an ontological exercise: it is the creation and bounding of a framework. It explains the distinguishing characteristics of how a phenomenon operates and what factors cause it to operate. It begins the process of making predictions and "forms the knowledge upon" actions taken to control the event.[17]

1. What is a Disaster?

A useful definition of a disaster for our purposes must describe a complex abstract problem, frame the environment in concrete terms, remove ambiguity from concepts, and clarify the essential goals. The challenge is to create an understanding that includes the type of definition, purpose, and audience as well as devising a definition that recognizes the need to separate conditions, characteristics, and consequences.[18] There were 32,367 automobile-related fatalities in 2011. This is a tragic and enormous loss of life, but it is not a disaster because it is not concentrated in time and space.[19]

Disaster research normally relies upon an implicit definition: an event that happens in a concentrated time with some negative impact on some social entity that is disruptive to generally accepted social life.[20] The *National Response Framework* defines

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[17] Ronald. W. Perry, "Disasters, Definitions and Theory Construction," in *What is a Disaster?* ed. Ronald W. Perry and Enrico L. Quarantelli (Philadelphia: Xlibris, 2005), 321.

[18] Enrico L. Quarantelli, "A Social Science Research Agenda for the Disasters of the 21st Century," in *What is a Disaster? New Answers to Old Questions*, ed. Ronald W. Perry, and Enrico L. Quarantelli (325–396) (Philadelphia: Xlibris, 2005), 333.

[19] U.S. Department of Transportation, "New NHTSA Analysis Shows 2011 Traffic Fatalities Declined by Nearly Two Percent" (NHTSA 47–12), press release, December 10, 2012, http://www.nhtsa.gov/About+NHTSA/Press+Releases/2012/New+NHTSA+Analysis+Shows+2011+Traffic+Fatalities+Declined+by+Nearly+Two+Percent

Charles Fritz, "Disasters," in *Contemporary Social Problems*, ed. Robert Merton and Robert Nisbet (651–694) (New York: Harcourt, Brace and World, 1961).

[20] Ibid.

disaster as politically mandated.[21] A mandated definition has politically meaning, but it doesn't express the complexity of the phenomenon.

The University of Delaware Disaster Research Center has expended significant effort to attempt to reach consensus among disaster researchers about the most common definition is a social event in social time.[22] A disaster is a disruption of the social system and the interconnected subsystems that define a modern society.

2. Catastrophe Criteria

The federal government recognizes that some catastrophic disaster events need to be specially categorized. The *National Response Framework* acknowledges that catastrophic incidents involve more stakeholders and require more resources and greater response.[23] The effort to classify events that have greater scope and complexity that are different than the challenges of a "simple" disaster is well documented.[24] The criteria used in this thesis were developed by E. L. Quarantelli and clearly defined the differences in "Catastrophes are Different from Disasters: Some Implications for Crisis."

- "Most or all of the community-built environment is heavily impacted."
- "Local officials are unable to undertake their usual work role, and this often extends into the recovery period." Many leadership roles may have to be taken by outsiders to the community.

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[21] U.S. Department of Homeland Security, *National Response Framework*.

[22] According to "Sorokin and Merton… physically based time-reckoning inexorably marches on in relatively homogeneous units, while social time unfolds with varying rhythms; sometimes rapidly, sometimes slowly, and sometimes with breaks (e.g., sleep or holidays). J. David Lewis, and Andrew J. Weigert, "The Structures and Meanings of Social Time," special issue, *Social Forces* 60, no. 2 (1981): 432–462; Fritz, "Disasters;" Perry, "Disasters, Definitions and Theory Construction," 315; Gary A. Kreps, "Future Directions in Disaster Research," *International Journal of Mass Emergencies and Disasters* 7, no. 3 (1989): 215–241;Samuel Henry Prince, *Catastrophe and Social Change, Based upon a Sociological Study of the Halifax Disaster* (New York: Columbia University, 1920).

[23] U.S. Department of Homeland Security, *National Response Framework*.

[24] Enrico L. Quarantelli, "Catastrophes are Different from Disasters: Some Implications for Crisis Planning and Managing Drawn from Katrina," Social Science Research Council, June 11, 2006, accessed June 1, 2014, http://understandingkatrina.ssrc.org/Quarantelli/; Ira Helsloot et al., eds., *Mega-crises: Understanding the Prospects, Nature, Characteristics, and the Effects of Cataclysmic Events* (Springfield, IL: Charles C Thomas, 2012); *Civil Support: Actions are Needed to Improve DOD's Planning for a Complex Catastrophe* (GAO-13-763) (Washington, DC: Government Accountability Office, 2013), http://www.gao.gov/assets/660/658406.pdf; Arnold M. Howitt, and Herman B. Leonard, "Beyond Katrina: Improving Disaster Response Capabilities" (PB-2006-2), *Taubman Center Policy Briefs*, 2006, http://www.hks.harvard.edu/content/download/70205/1253630/version/1/file/katrina_final.pdf, 18–25

- "Help from nearby communities cannot be provided."
- "Most, if not all, of the everyday community functions are sharply and concurrently interrupted."
- "The mass media system constructs catastrophes even more than they do disasters."
- "The political arena becomes even more important… National government and very top officials become involved."[25]

3. Catastrophic Response Cycle

The disaster management cycle is an effort to organize and explain phenomena. The four phases are defined: (1) mitigation, (2) preparedness, (3) response, and (4) recovery.[26] In "Agility and Discipline: Critical Success Factors for Disaster Response," John R. Harrald has subdivided the response phase in complex catastrophic events; this differentiates and illustrates the dynamic changes to objectives and functions through time (see Figure 2).[27] The initial response (reaction and mobilization) reflects the chaos of the event and the emergent forces that begin to self-organize in reaction while convergent forces are mobilizing to respond. The organizational integration phase brings emergent and convergent forces together. This phase requires these forces to evolve into functioning organizations that identify needs and provide services. The integration and the efficiency of these groups are tied to the capabilities of the communication systems that support them. The convergent groups provide resources and services that are beyond the capacity of the emergent groups. Success in these two phases leads to a production phase: "the response organization is fully productive, delivering needed services as a matter of routine."[28] The final phase is the transition phase in which the convergent forces demobilize, and the recovery stage can begin. In catastrophic events, a significantly large convergent force is required for an extended period. Harrald states,

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[25] Quarantelli, "Catastrophes are Different from Disasters," 3–6.

[26] Bruce L. Lindsay, *Federal Emergency Management: A Brief Introduction* (Washington, DC: Congressional Research Service, 2012), https://www.fas.org/sgp/crs/homesec/R42845.pdf

[27] John R. Harrald, "Agility and Discipline: Critical Success Factors For Disaster Response," *The Annals of the American Academy of Political and Social Science* 604, no. 1 (2006): 256–272.

[28] Ibid., 260.

"planning for and transition to this force must be managed."[29] He also notes, "The success factors in each stage are linked; success in one phase is a precondition for success in the next."[30]

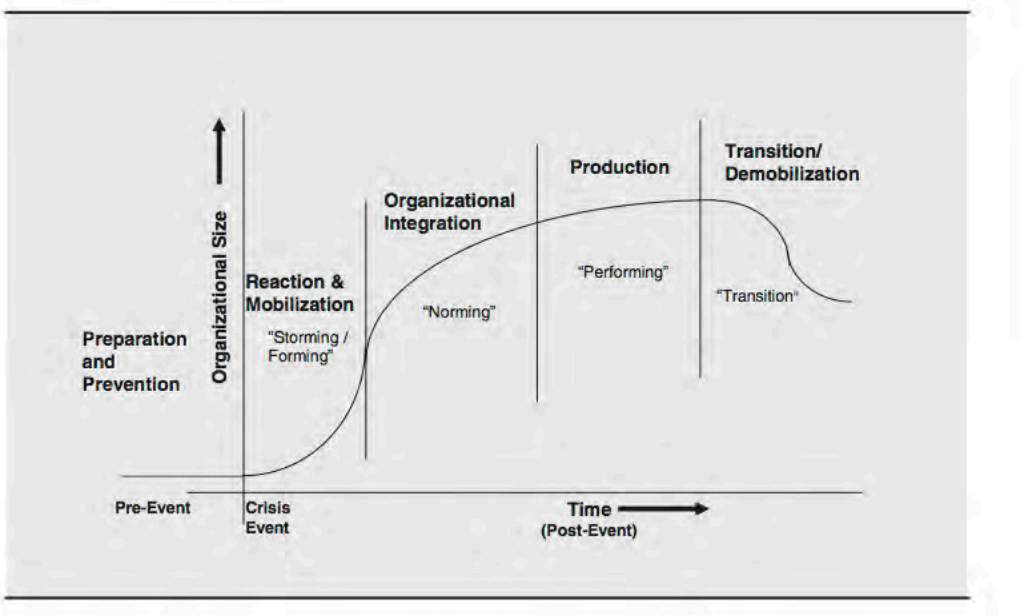

Figure 2. Stages of Crisis Response Organizational Size Versus Time[31]

Just as disasters are qualitatively and quantitatively different from everyday emergencies, catastrophes are of such a scale and impact to the social structure that they need special attention. The effects on organizations, communities, and society require different planning and response than do major disasters. Quarantelli states that reactions by individuals to disasters and catastrophes are both similar and good.[32] However, he finds major changes at the organizational level that lead to poorer response:

- There will be even slower organizational assessments of the problems in the situation.
- There will be poorer and more inaccurate information flows between agencies

[29] Ibid., 260.

[30] Ibid.

[31] Ibid., 261.

[32] Quarantelli, "Catastrophes are Different from Disasters," 6.

- There will be substantially greater difficulty in coordinating the organized response for an incident command system (that is a dubious arrangement even for disasters, and even less appropriate for a catastrophe)[33]

These major differences are all influenced by communication.

Fritz states that disasters are an "event concentrated in time and space, in which society or one of its subdivisions undergoes physical harm and social disruption, such that all or some essential functions of the society or subdivision are impaired."[34] Catastrophe is not just greater devastation; it is "graver threat, uncertainty, urgency.[35] The emphasis for responders is on the social aspect of the event, the disruption of society, and the factors involved in the restoration of normality. The modern technical world is intensely interconnected. A massive disruption of infrastructure, a population at hazard, and the inability to communicate extends the chaos of the response phase. The focus of crisis management is to accelerate the restoration to stability. Catastrophic events are of a complexity and scope such that crisis management needs to reevaluate organizational models, policy, and strategy.

ICS is inappropriate for a routine emergency, such as an automobile accident. Routine emergencies are qualitatively and quantitatively different from disasters, in which ICS functions well. However, the current crisis response planning and management practices approach catastrophes as large-scale disasters. Managing this type of crisis requires a change. It requires an effective and realistic communication strategy and an organization that can respond to the forces at work and the environment in a catastrophe.

B. CHAOS AND COMPLEXITY

Defining a phenomenon as chaotic and complex requires an understanding of how those words describe intricately interrelated parts in the universe and how those parts interact. "The greatest challenge today in all of science," writes Wilson "is the accurate

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[33] Ibid.

[34] Fritz, "Disasters," 655.

[35] Helsloot et al., *Mega-crises*, 5.

and complete description of complex systems."[36] Brian Castellani created a map of complexity science that illustrates the breadth of scholarship and research that have been performed in this field (see Figure 3).[37] This visualization puts into perspective the difficulty of terming a system as complex but not understanding the ramifications. David Byrne defines complexity using three concepts: complexity is nonlinear, it deals with realism as an ontological principle, and it is evolutionary. In terms of this thesis, the holistic environment is the intersection and interrelation of social and natural systems.[38] A catastrophe creates a severe nonlinear disruption of the social system. The emerging forces self-organize, and networks grow and evolve.[39] The social disruption releases forces (emergent and convergent) that require some manner of communication to integrate.[40] Furthermore, the social forces are shaped following social, systems, and network theories.[41] The objective of crisis response is to limit the destructive, chaotic state (return the social bounds to "normality") by harnessing and organizing the complex forces of emergence and convergence.

Disaster research (a branch of the social sciences) has devoted significant scholarly effort to advance and apply complexity science to understand the interrelated

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[36] Edward O. Wilson, *Consilience: The Unity of Knowledge* (New York: Vintage Books, 1999), 93.

[37] Brian Castellani, "Map of Complexity Science," accessed July 15, 2014, http://scimaps.org/mapdetail/map_of_complexity_sc_154

[38] David S. Byrne, *Complexity Theory and the Social Sciences* (New York: Routledge Publishing, 1998).

[39] Byrne, *Complexity Theory and the Social Sciences*, 1–3; Ilya Prigogine, Isabelle Stengers, and Alvin Toffler, *Order out of Chaos* (New York: Bantam Books, 1984); Stuart Kauffman, *The Origins of Order* (London: Oxford University Press, 1993).

[40] Kauffman, *The Origins of Order*; Prince, *Catastrophe and Social Change*; Charles Fritz, and John H. Mathewson, *Convergence Behavior in Disasters: A Problem in Social Control* (Washington, DC: National Academy of Sciences, 1957).

[41] Byrne, *Complexity Theory and the Social Sciences*; Niklas Luhmann, "Systemtheorie, Evolutionstheorie und Kommunikationstheorie [System Theory, Evolution Theory, and Communication Theory]," in: *Soziologische Aufklärung 2* [The Differentiation of Society], trans. Stephen Holmes and Charles Larmore (Opladen, Germany: Westdeutscher Verlag), 193–203; Albert-László Barabási, *Linked: The New Science of Networks* (Cambridge, MA: Perseus Publishing 2002); Ludwig von Bertalanffy, "An Outline of General System Theory," *British Journal for Philosophy of Science* 1, no. 2 (1950): 134–165; Robert Axelrod, and Michael D. Cohen, *Harnessing Complexity* (New York: Basic Books, 2000); Per Bak, Chao Tang, and Kurt Wisenfeld, "Self-Organized Criticality: An Explanation of 1/f Noise," *Physical Review Letters* 59, no. 4 (1987): 381–384.

dynamic forces.[42] These are a few of the many scholars who have attempted to define and explain how complexity and nonlinear theories represent reality and need consideration in crisis management.

[42] Prince, *Catastrophe and Social Change*; Fritz, and Mathewson, *Convergence Behavior in Disasters*; Byrne, *Complexity Theory and the Social Sciences*; Thomas E. Drabek, and David A. McEntire, "Emergent Phenomena and Multi-organizational Coordination in Disasters: Lessons from the Research Literature," *International Journal of Mass Emergencies and Disasters* 22, no. 2 (2002): 197–224; Gary Kreps, and Susan L. Bosworth, "Disaster, Organizing, and Role Enactment: Structural Approach," *American Journal of Sociology* 99, no. 2 (1993): 428–463. Louise K. Comfort, "Self-Organization in Complex Systems," *Journal of Public Administration Research & Theory* (1994): 393–410; Ted G. Lewis, "Cause-and-Effect or Fooled by Randomness?" *Homeland Security Affairs* 6 (2010); Robert Stallings, and Enrico L. Quarantelli, "Emergent Citizen Groups and Emergency Management," *Public Administration Review* 45 (1985): 93–100; Donald P. Moynihan, "The Network of Governance of Crisis Response: Case Studies of Incident Command Systems," *Journal of Public Administration Research and Theory Advance Access* 19 no. 4 (2009): 1–21; Michael J. Bolton, and Gregory B. Stolcis, "Overcoming Failure of Imagination in Crisis Management: The Complex Adaptive System," *The Innovation Journal: The Public Sector Innovation Journal* 13, no. 3 (2008): 1–12, http://www.innovation.cc/scholarly-style/bolton-stolcis3dec2008v13i4.pdf; Patrick Lagadec, "A New Cosmology of Risks and Crises: Time for a Radical Shift in Paradigm and Practice," *Review of Policy Research* 26, no. 4 (2009): 473–486, http://www.patricklagadec.net/fr/pdf/New_Cosmology.pdf; Charles F. Parker, and Eric Paglia, "Hurricane Katrina: The Complex Origins of a Mega-Disaster," in *Mega-crises: Understanding the Prospects, Nature, Characteristics, and the Effects of Cataclysmic Events*, ed. Ira Helsloot, Arjen Boin, Brian Jacobs, and Louise K. Comfort (51–65) (Springfield, IL: Charles C Thomas, 2012).

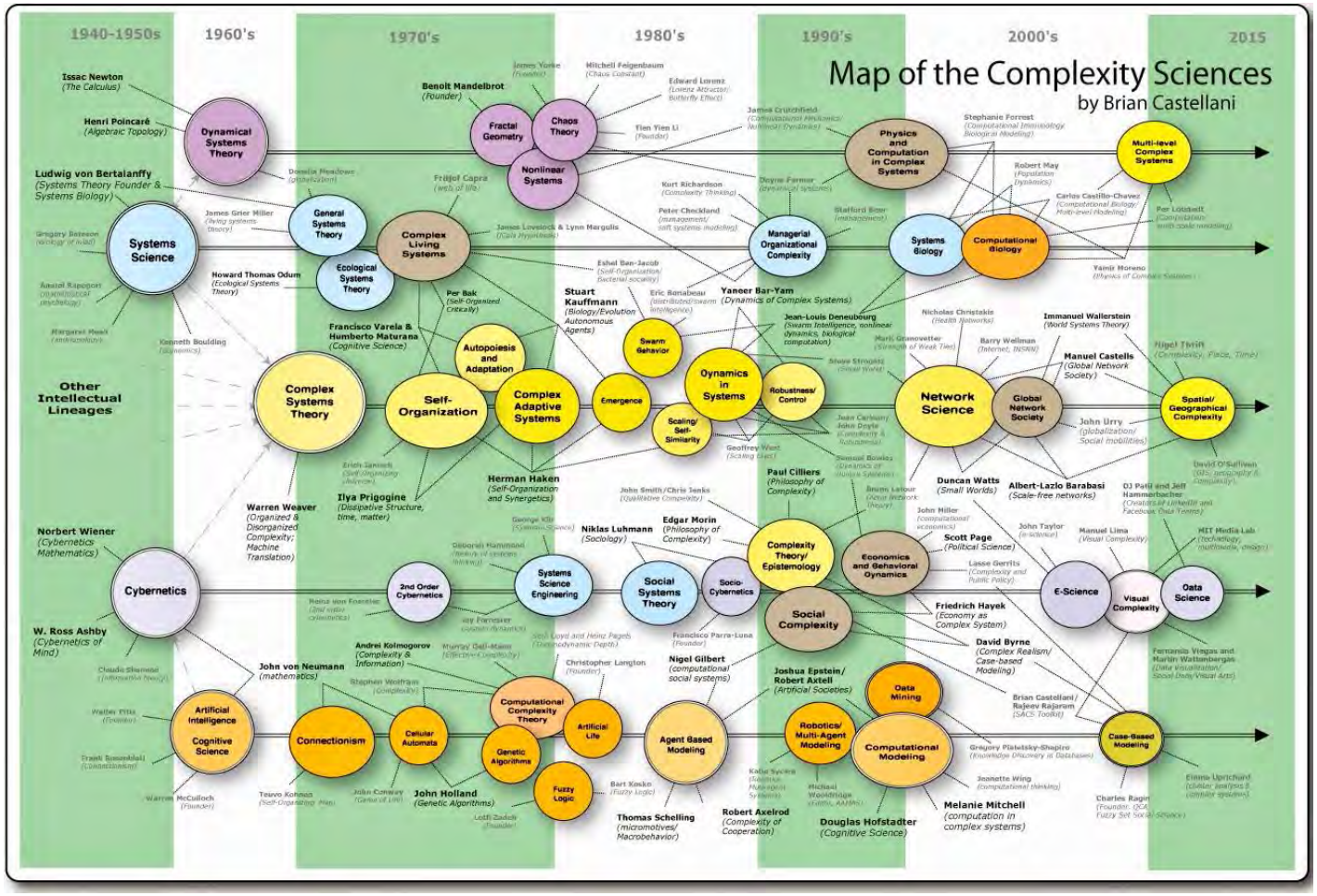

Figure 3. Complexity Sciences[43]

[43] Castellani, "Map of Complexity Science."

C. CHAOS

"Life is… nonlinear. And so is everything else of interest."

Heinz Pagels[44]

High levels of uncertainty and unpredictability characterize disaster response; these are nonlinear events. The common goal of crisis response is to bring the affected area back to a stable state for recovery to begin. Crisis exposes a cloud of uncertainty for emergent and convergent response that is akin to the fog of war.[45] A chaotic state is described as confused and disorganized. In a linear system, the relationship between relevant variables appears stable; cause and effect are proportional. Proportionality is not reflective of reality, and a system as complex as society is always nonlinear. In linear cause and effect thinking, a big change will have big consequences. A complex human crisis response system is robustly nonlinear.[46] According to Kiel, "Nonlinearity refers to behavior in which the relationships between variables in a system are dynamic and disproportionate."[47] In addition, small changes can have big or unexpected consequences and often defy linear methodologies to forecast them.[48] The systems are extremely sensitive to initial conditions, decisions, and actions. Actions taken within the initial chaos will have much greater and more unpredictable results in nonlinear systems than linear ones.[49]

Crisis response is not a static system; there are constant changes in system state over time. A catastrophe is not similar to an event like a house fire that has a simple

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[44] Heinz Pagels, *The Dreams of Reason* (New York: Simon and Schuster, 1988).

[45] L. Douglas Kiel, "Chaos Theory and Disaster Response Management: Lessons for Managing Periods of Extreme Instability," in *What Disaster Response Management Can Learn from Chaos Theory, California Emergency Medical Services Authority–Conference Proceeding*, ed. Gus Koehler, May 1995, https://www.library.ca.gov/CRB/96/05/over_12.html

[46] Byrne, *Complexity Theory and the Social Sciences*.

[47] Kiel, "Chaos Theory and Disaster Response Management," 1.

[48] Kiel, "Chaos Theory and Disaster Response Management;" Edward N. Lorenz, "Deterministic Nonperiodic Flow," *Journal Atmospheric Sciences* 20, no. 2 (1963): 130–141.

[49] Lorenz, "Deterministic Nonperiodic Flow;" Harvard Humanitarian Initiative, *Disaster Relief 2.0: The Future of Information Sharing in Humanitarian Emergencies* (Washington, DC: UN Foundation & Vodafone Foundation Technology Partnership, 2011), 20.

straight-line extension.[50] The chaotic systems behavior during a catastrophic event is limited by boundaries that severely diverge from the perceived normal. Behavior "refers to change in organizations and how organizational data evolve over time."[51] Nonlinear systems have three types of distinct behavior over time:

- convergence to stability or equilibrium
- stable oscillation
- chaos

Convergence to stability or equilibrium is a simple nonlinear behavior where from an initial point, the system quickly reaches and maintains stability. This behavior is not considered reflective of real-world systems but of an artificial construct of an ideal system. All complex systems experience variation over time, and this accounts for volatility and dynamism. Stable oscillation is reflective of normal patterns of life. This system reflects smooth patterns of predictable, incremental change.

Chaos is characterized by behavior that seems random and disorderly over time but actually has definable parameters.[52] While chaotic behavior appears disorderly, because it does not retrace prior sequences of behavior, it does behave in a recognizable pattern. The outcomes of this behavior occur within definable parameters; potential outcomes are not infinitely possible. According to Kiel, "Chaos thus looks like random behavior but is really unstable behavior over time that stays within clear boundaries."[53]

The goal of crisis response is to manage chaos: to bring order and stability. The research on controlling chaotic environments has resulted in three fundamental methods: parameters, perturbations (attractors), and orbits.[54]

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[50] Thomas Drabek, "Disaster in Aisle 13 Revisited," in *Disasters, Collective Behavior, and Social Organization*, ed. Russell Dynes and Kathleen Tierney (26–44), (Newark, NJ: University of Delaware Press, 1994), 30.

[51] Kiel, "Chaos Theory and Disaster Response Management," 2.

[52] Ibid., 4.

[53] Ibid., 5.

[54] Kiel, "Chaos Theory and Disaster Response Management," 3; Edward Ott, Celso Grebogi, and James A. Yorke, "Controlling Chaos," *Physical Review Letters* 64, no. 11 (1990): 1190–1193; William Ditto, and Louis Pecora, "Mastering Chaos," *Scientific American* 269, no.2 (August 1993): 78–84.

- Altering the parameters: limiting the degrees of freedom or extent of behavior available to a system. The concept is to control behavior to create greater stability and predictability. The problem is the destructive forces are often beyond human control, and the capacity to mitigate it will be overwhelmed. This method is represented by a management theory that in order to achieve managerial goals, strict systems controls are needed to achieve levels of certainty and predictability.[55]
- Introduction of attractors: the disproportional sensitivity of chaos can be brought back to a more ordered and stable state. The intent is to introduce "perturbations" to create a nonlinear effect, resulting in a phase shift from erratic to fluid behavior.[56] These perturbations can be thought of as a "way of guiding purposeful action toward desired outcomes, although to do so we have to know a lot and be able to manage what we know in rather different ways."[57]
- Alter "orbits": the concept is to alter the "orbit" of a system from chaos toward stability around systems attractors.[58]

Attractors and orbits are interventions into a nonlinear system. These offer crisis response a possible avenue to manage chaos. Crisis management using perturbation must identify pressure points. This is a learning and adaptive approach that requires continual feedback to find the points that return the best results. This approach requires also open lines of communication and flexibility in management.[59] The third approach for controlling chaos (altering orbits) is consistent with cybernetic approaches to management. Good organizations need the ability to be "self-connecting," self-organizing, and require effective methods of communication.[60] Kiel explains, "These approaches rely on constant feedback to ensure that work and administrative systems are continuously adjusting to environmental and organizational demands and changes. Again, we see the importance of communication and feedback in efforts to control chaos."[61]

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[55] Kiel, "Chaos Theory and Disaster Response Management," 7.

[56] Ibid.

[57] Byrne, *Complexity Theory and the Social Sciences*, 16–17.

[58] Kiel, "Chaos Theory and Disaster Response Management," 7.

[59] Comfort, "Self Organization in Complex Systems."

[60] Ludwig von Bertalanffy, "An Outline of General System Theory;" William R. Ashby, "Principles of the Self-organizing System," *Journal of General Psychology* 37, no. 2 (1947): 266–267.

[61] Kiel, "Chaos Theory and Disaster Response Management," 7.

Comfort's work on crisis response emphasizes the importance of modern information and communications technology as essential to accelerate the self-organization process.[62]

The response forces (emergent and convergent) need communications—the ability to exchange and share information. Crisis management needs creative ways to manage chaos.[63] In addition, chaos theory is a vital issue in crisis management: chaos inhibits decision making, coordination, initiative and creates inefficiencies.[64] Ali Farazmand states that since chaos is an expected and a normal part of catastrophic events, surprise, novelty and complexity paralyze response systems and produce more chaos.[65] There is an urgent need within the crisis management community to develop the ability to manage "chaos and surprise."[66] The importance of understanding the dynamics of chaotic environments is that linear management techniques are ineffective if not counterproductive. The response community needs an adaptable organizational structure that has flexibility and agility and enables continuous flow of information.[67] An alternative to a linear approach is an organizational structure that has command and control attributes that are open and dynamic.[68]

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[62] Comfort, "Self Organization in Complex Systems."

[63] Kiel, "Chaos Theory and Disaster Response Management."

[64] Kiel, "Chaos Theory and Disaster Response Management;" John C. Pine, "The Contributions of Management Theory and Practice to Emergency Management," in *Disciplines, Disasters and Emergency Management: The Convergence of Concepts Issues and Trends from the Research Literature*, ed. David A. McEntire (196–205) (Springfield IL, Charles C Thomas 2007).

[65] Ali Farazmand, "Learning from the Katrina Crisis: A Global and International Perspective with Implications for Future Crisis Management," special issue, *Public Administration Review* (December 2007): 149–159.

[66] Ibid., 156.

[67] Harrald, "Agility and Discipline."

[68] Kiel, "Chaos Theory and Disaster Response Management;" Ebru Caymaz, Volkan Akyon, and Fahri Erenel, "Chaos Management in Disasters from a Military Point of View," Stockholm International Peace Research Institute, 2013, accessed July 14, 2014, http://www.sipri.org/research/armaments/milex/ICES2013/papers/archive/caymaz-ekeon-erenel-chaos-management-in-disasters-from-a-military-point-of-view; David Levy, "Chaos Theory and Strategy: Theory, Application, and Managerial Implications," *Strategic Management Journal* 15 (summer 1994): 167–178; Dick A. Buck, Joseph E. Trainor, and Benigno E. Aguirre, "A Critical Study of the Incident Command System and NIMS," *Journal of Homeland Security and Emergency Management* 3, no. 3 (2006): LRC01–LRC29.

D. SYSTEMS OF SYSTEMS

In an article in Nature Physics, Barabási remarks, "The daunting reality of complexity research is that the problems it tackles are so diverse that no single theory can satisfy all needs."[69] A catastrophic event disrupts the social system. It is impossible to understand the complexity unless the interconnected principles of systems are defined and also how that system can self-organize and reconnect in a destabilized nonlinear state. Barabási notes, "Although no theory can satisfy all needs, what we can strive for is a broad framework within which most needs can be addressed."[70] A social system requires a clear description of systems.

In nonlinear systems thinking cause and effect are not proportionate. The web of complementary and supporting concepts and theories requires a holistic approach. The idea that communication is the essential ingredient for reordering a chaotic social system needs to be addressed, including how these concepts are linked together as a system. Moreover, it is essential to understand how complex social systems rely on communication and the manner in which communication is restored when confronted by massive disruption. Systems theory defines the functional mechanics and the relationships of sub-systems and components.[71] The disrupted social system will reorganize, and the core element for self-organization is communication.[72] The systems that emerge require a communication system. The emergent communications system will evolve along lines following network theory.[73]

1. Systems Theory

Since a catastrophe is a disruption of the social system, it is essential to understand what a system is. Ludwig von Bertalanffy developed the general system

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[69] Albert-László Barabási, "The Network Takeover," *Nature Physics* 8 (2012): 15.

[70] Ibid., 14–16.

[71] von Bertalanffy, "An Outline of General System Theory."

[72] Luhmann, "Systemtheorie, Evolutionstheorie und Kommunikationstheorie;" Loet Leydesorff, *A Sociological Theory of Communication: The Self-Organization of Knowledge-Based Society* (Boca Raton, FL: Universal-Publishers, 2001).

[73] Barabási, *Linked: The New Science of Networks*; Mark E. J. Newman, "The Structure and Function of Complex Networks," *SIAM Review* 45, no. 2 (2003): 167–256.

theory to describe the collection of principles, models, and laws that are valid for "systems" in general.[74] He was looking for universally applicable theory (or an organized body of knowledge) to produce a "logico-mathematical discipline… that is applicable to all sciences that are concerned with systems."[75] His work focused on a "holistic" approach, the interrelationships that defined how individual components together form the systems. A system is not just the sum of its parts. It also represents a collection of elements, interconnections, or relationships, and a function or purpose.[76] The relationships within a system are the communications flows that allow a system to function.[77] Those self-regulating or self-organizing dynamic systems require constant communications (feedback).[78] Central to Bertalanffy's work[79] is the idea of the open systems, which are from studies in thermodynamics and biology. He calls "a system closed if no materials enter or leave it. It is open if there are inflow and outflow, and therefore change of the component materials."[80]

These concepts have had great effect on cybernetics, pioneered by Norbert Wiener and W. Ross Ashby. Cybernetics is the "study of control and communication" in complex systems.[81] A system must control behavior, process and react to information, and adapt as a result.[82] A catastrophic event represents an open, dynamic, disordered social system. The inflow and outflow are the convergent and emergent forces. These forces requires the restoration of a communication system. The system requires the formation of a network that passes information between and within, and this links

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[74] von Bertalanffy, "An Outline of General System Theory;" Newman, "The Structure and Function of Complex Networks."

[75] Ibid., 140.

[76] Donella H. Meadows, *Thinking in Systems* (White River Junction, VT: Chelsea Green Publishing Co., 2008).

[77] Ibid.

[78] Ibid.

[79] von Bertalanffy, "An Outline of General System Theory," 156.

[80] Ibid., 156.

[81] Norbert Wiener, *Cybernetics or Control and Communication in the Animal and the Machine* (Cambridge, MA: MIT Press, 1948).

[82] Ibid.

individuals and communities as well as integrates the converging efforts. The ability to exert control over chaotic environments by altering "orbits" requires continuous tracking and feedback.[83] This concept is closely related to cybernetic theory.[84] Network management of evolving systems requires close monitoring and careful intervention. The promotion of organizational connectivity or increasing an entity's visibility within the system alters the "orbit." These altered orbits become basins of attraction that have the ability to improve the restoration of stability.

2. Social Theory

According to Niklas Luhman, a complex social system requires a communication system.[85] His article, "Systemtheorie, Evolutionstheorie und Kommunikationstheorie" organizes his grand social systems theory into three interconnected themes:

- systems theory
- communication theory
- evolution theory[86]

In Luhmann's work, the elementary core for social systems is communication.[87] A social systems is made up of systems of communication. Society is defined as the most complex and comprehensive social system. A complex system requires information that is processed, distributed, and returns in a feedback loop.

Niklas Luhmann's general social theory is built on the concept that a social system's self-organization requires self-referentiality.[88] He bases his self-organization of social systems theory on the work of Humberto Maturana and Franciso Varela in the

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[83] Kiel, "Chaos Theory and Disaster Response Management."

[84] Ibid.

[85] Luhmann, "Systemtheorie, Evolutionstheorie und Kommunikationstheorie."

[86] Leydesdorff, *A Sociological Theory of Communication*.

[87] Luhmann, "Systemtheorie, Evolutionstheorie und Kommunikationstheorie."

[88] Niklas Luhmann, *Social Systems*, trans. Eva M. Knodt (Stanford CA: Stanford University Press, 1995).

book *Autopoiesis and Cognition: The Realization of the Living*.[89] These concepts are supported by Ilya Prigogine and Isabelle Stengers, W. Ross Ashby, and Stuart Kauffman's work on self-organization.[90] For Luhmann, the essential elements of a social system are self-producing dynamic communications. As long as communication continues and encourages new lines of communication in a dynamic system, a social system can self-organize. "Society should no longer be considered as composed of human beings," Luhmann states, "but as consisting of communications."[91] A disrupted society is one in which communications are difficult or impossible. Social action requires humans (nodes) to communicate via links on a network to other humans (nodes). Recovery entails restoration of a communications system that involves growth and recognizes the importance of feedback. Leot Leydesorff felt that communication and communication systems were vague and needed substance to be understood.[92] He broke the system down into what needed to be communicated, mechanisms of communication within specified sub-systems, and how they interact. Leydesorff argued that it was incorrect to assume self-organization will not itself devolve into crisis.[93]

All of these researchers are in agreement that all social systems are special communications systems and for self-organization to be successful stabilization of the environment is crucial.[94] However, Leydesorff asserts that the process cannot be taken for granted. In Luhmann's work, a reaction such as a catastrophic event (that amounts to the destruction of the social system and the interaction within the environment) requires system differentiation, that is, a division of a complex system into identical subsystems.[95] The impact of the catastrophe covers a wide area, but the communities themselves are

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[89] Humberto Maturana, and Franciso Varela, *Autopoiesis and Cognition: The Realization of the Living* (Amsterdam: Springer, 1980).

[90] Prigogine, Stengers, and Toffler, *Order out of Chaos*; Ashby, "Principles of the Self-organizing System;" Kauffman, *The Origins of Order*.

[91] Luhmann, *Social Systems*; Leot Leydesdorf, "Is Society a Self Organizing System?" *Journal of Social and Evolutionary Systems* 16, no. 3 (1993): 341.

[92] Leydesorff, *A Sociological Theory of Communication*, 15.

[93] Ibid.

[94] Ibid., 20.

[95] Niklas Luhmann, "Differentiation of Society," *Canadian Journal of Sociology* 2, no. 1 (1977): 29–53.

separately affected. From a destabilized dynamic social standpoint (combined with the disruption of communications), the communities represent initially independent smaller disasters within the context of the overall catastrophe. Luhmann believes this is the structural technique for solving the temporal problem of complex systems existing in complex environments.[96]

3. Network Theory

Modern network theory is relatively new. Network theory "aims to understand the origins and characteristics of networks that hold together the components in various complex systems."[97] Complexity strives to understand the relationship between things; network theory describes the characteristics and forces that these relationships exhibit. According to Barabási, the emergence of the World Wide Web, Internet, and historic network theory have "led to the discovery that despite the many differences in the nature of the nodes and the interactions between them, the networks behind most complex systems are governed by a series of fundamental laws that determine and limit their behavior."[98] Barabási also notes that the "holistic" approach to complexity reduced systems to the sum of their parts. According to Barabási, "Reductionism deconstructed complex systems, bringing us a theory of individual nodes and links. Network theory is painstakingly reassembling them, helping us to see the whole again."[99] Complex systems will not be understood unless there is an understanding of how these systems are supported by an elaborate web of interconnections and relationships between individual components.[100] The changes in networking environments and the ability to map millions of links and nodes lead to a new understanding of the properties that define living networks. For the sake of brevity, we will avoid mapping the evolution of modern network science from the works on random networks by Erdős and Rényi, the small-world networks of Stanley Milgram, Duncan Watts and Stephen Strogatz, the importance

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[96] Ibid.

[97] Barabási, "The Network Takeover," 15.

[98] Ibid.

[99] Ibid.

[100] Ibid., 6–7.

of weak links by Mark Granovetter, the natural formation of hubs and connectors by Albert-László Barabási and Réka Albert, or the consequence of the power law to network distribution by Vilfredo Pareto. The importance of network science is the understanding how disordered and disrupted networks emerge and evolve following a common set of fundamental laws.[101]

A simple network is described as a collection of nodes (vertices or actors) connected in some manner via links (edges or ties). Social network studies are primarily focused on social interrelations through centrality and connectivity. Centrality of a node measures the number of linkages as compared to other nodes. The highest linked nodes are considered the best connected or most influential, and the most connected nodes are also known as hubs. Connectivity determines the relationship of connections of individual nodes through the network. Mark Newman has divided networks into four loose categories: social networks, information networks, technological networks, and biological networks.[102] The first three are of the most interest within the disorder following a catastrophic event. Following the impact of the event, the social network is shattered. Cascading infrastructure failures lead to the failure of the technology networks and the ability to satisfy the basic information needs is chaotic or non-existent.

As modern systems and networks are more tightly coupled, failure in one system (i.e., power) can cause cascading failures. The failure of communications is the removal of a network that is central to social order. The reformation or self-organization of real-world networks in this complex environment follows basic network rules for growth. The two most popular non-random models of networking that rely on the power-law distribution are small-world and scale-free.[103]

The power-law distribution is fundamental to both models. The power law degree distribution model (sometimes called the 80–20 rule) expresses the relationship between

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[101] Ibid.

[102] Newman, "The Structure and Function of Complex Networks."

[103] Duncan Watts, and Steven H. Strogatz, "Collective Dynamics of 'Small-World' Networks," *Nature* 393, no. 4 (1998): 440–442; Albert-László Barabási, and Albert, Réka, "Emergence of Scaling in Random Networks," *Science* 286, no. 5439 (1999): 509–512.

two quantities (see Figure 4). According to Watts, "The distribution of the number of network neighbors—the degree distribution—is typically right-skewed with a 'heavy tail,' meaning that a majority of nodes have less-than-average degree and that a small fraction of hubs are many times better connected than average."[104] This is described by Barabási and Reka as an:

> independent of the system and the identity of its constituents, the probability P(k) that a vertex in the network interacts with k other vertices decays as a power law, following $p(k) \sim k^{-\alpha}$. This result indicates that large networks self-organize into a scale-free state.[105]

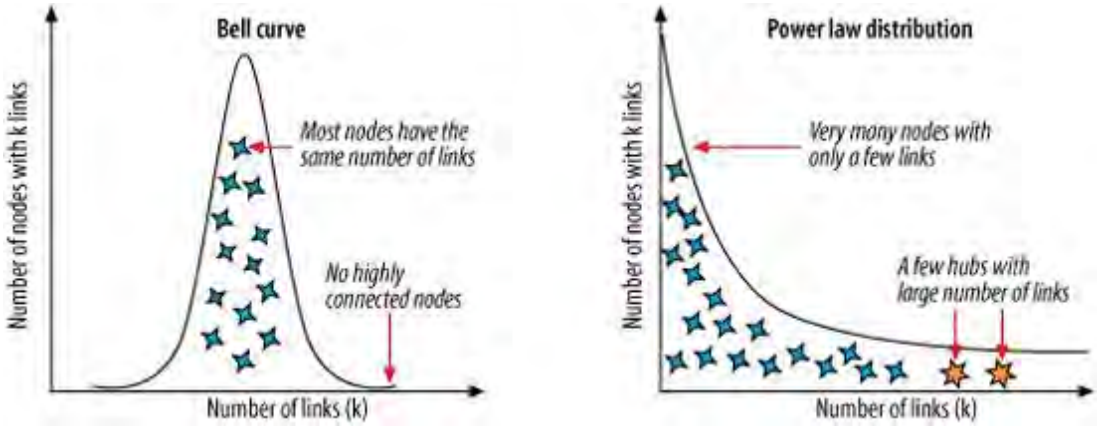

Figure 4. Normal and Power Law Distribution[106]

In the article, "Collective Dynamics of 'Small-World' Networks," Watts and Strogatz built on the popular "six-degrees" of separation to explain how real-world networks are neither strictly regular nor completely random (see Figure 5).[107] The natural (and efficient) state of large real-world networks (social, technical, biological, or information) will result in a number of large clusters (highly connected nodes) with small

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[104] Duncan Watts, "The 'New' Science of Networks," *Annual Review Sociology* 30 (2004): 243–270.

[105] Barabási, and Réka, "Emergence of Scaling in Random Networks."

[106] Peter Morville, *Ambient Findability: What We Find Changes Who We Become* (Sebastopol, CA: O'Reilly Media, 2005).

[107] Watts, and Strogatz, "Collective Dynamics of 'Small-World' Networks."

linkage paths between nodes.[108] Using the "prisoner's dilemma" model, Watts and Strogatz found decreasing levels of cooperation testing the various stratagems as short cuts decrease or when randomness increases.[109]

Barabási and Reka revealed large networks with complex topologies self organize into a scale-free state.[110] This study focused on emergent network properties in complex large networks. Additionally, Barabási and Reka came to the conclusion that two generic mechanisms were at work: "(i) networks expand continuously by the addition of new vertices (nodes or actors), and (ii) new vertices attach preferentially to sites that are already well connected."[111] This "preferential attachment" is central to the understanding that in real-world networks, there are hubs and clusters that are essential to network growth. They are considered "ubiquitous, a generic building block in our complex interconnected world."[112]

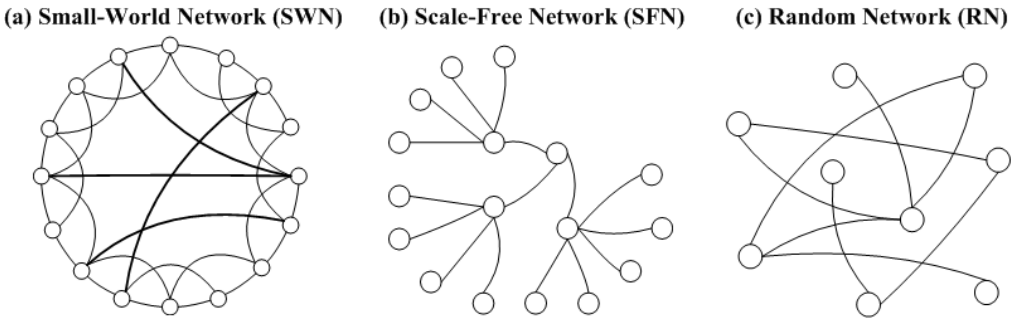

Figure 5. Small-world, Scale-free and Random Networks[113]

The ability to assert control over a chaotic environment is the use of perturbations and orbits.[114] These controls represent interventions during the catastrophic event that

[108] Ibid., 440.

[109] Ibid.

[110] Barabási, and Réka, "Emergence of Scaling in Random Networks."

[111] Ibid., 509.

[112] Barabási, *Linked: The New Science of Networks*, 105.

[113] Chung-Yuan Huang, Chuen-Tsai Sun, and Hsun-Cheng Lin, "Influence of Local Information on Social Simulations in Small-World Network Models," *Journal of Artificial Societies and Social Simulation* 8, no. 4 (2005), http://jasss.soc.surrey.ac.uk/8/4/8.html

can speed the return to stability. The perturbations are the rapid telecommunications and technology teams (RTAT) and HFN principles that are injected into the environment as attractors, which create numerous basin of attraction where they operate). These basins of attraction are hubs—highly connected centers supported by ICT efforts. However, the lack of ICT support will the inhibit growth of these hubs. These hubs will serve as organizing points, the focus of local communication and networking efforts, the engine for self-organization and adaption, and the integrator of convergent efforts. The hubs naturally form as networks grow and self-organize and become orbits.

Barabási finds that network evolution is governed by growth, preferential attachment, and fitness attributes.[115] A communications strategy requires an understanding of how these mechanisms work. This strategy seeks to create, support, and expand HFNs, and one primary objective is to create an environment that promotes network growth. Improving connectivity raises the number of competitors vying for attention within the network. Dynamic network evolution will develop highly connected nodes, or hubs. These hubs develop following preferential attachment and fitness attributes. Preferential attraction describes the phenomena where nodes that have the greatest number of links are most likely to receive new links, evolving into hubs.[116]

The qualities of a node, the ability to provide services, quality of its products are examples of fitness. Fitness explains how late-comers to a network environment compete and overcome an initial lack of links.[117] This concept describes how Google could come from relative obscurity to becoming the biggest and most popular search engine.[118] ICT support is the limiting factor.

Greater interconnection is essential to better response, but this can cause problems if not managed. The Haiti earthquake response had greater connectivity and unmanaged,

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[114] Ott, Grebogi, and Yorke, "Controlling Chaos;" Kiel, "Chaos Theory and Disaster Response Management;" Ditto, and Pecora, "Mastering Chaos."

[115] Barabási, *Linked: The New Science of Networks*.

[116] Barabási, and Réka, "Emergence of Scaling in Random Networks."

[117] Barabási, *Linked: The New Science of Networks*, 157–158.

[118] Ibid., 143.

it lead to information overload.[119] Though there are information management challenges, efforts to accelerate linkage will create a network that will conform to network evolution theories. The highly connected hubs will become orbits around which alter nonlinear environment boundaries. These hubs will be centers of recovery or influence.[120] Additionally, these highly connected hubs represent individual localized basins of attraction within the chaotic environment.[121] Without convergent intervention applying a strategy that strives to create HFNs, the formation and organization will be slow. A successful strategy will aggressively and hastily reestablish and expand the communications networks. These emergent networks require significant effort to manage the vast amounts of data inflows.

E. EMERGENCE AND CONVERGENCE

Catastrophes release massive social forces. Though all the forces are an emergent social response, there needs to be a differentiation. The forces from within the affected region and the disrupted population are the emergent forces. The convergent force is the external response from outside the affected area directed toward the event. These two forces are separated and divided by the failure of information and communications subsystems.

A catastrophic event creates a massive disruption in a highly structured complex social system (and the interrelated subsystems). Emergence in complex systems is the collective behavior that drives the restoration of order and structure.[122] This natural process "leads to the appearance of a structure not directly described by the defining

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[119] Harvard Humanitarian Initiative, *Disaster Relief 2.0*.

[120] Eva Törnqvist, Johan Sigholm, and Simin Nadjm-Tehrani, "Hastily Formed Networks for Disaster Response: Technical Heterogeneity and Virtual Pockets of Local Order," in *Proceedings of the 6th International ISCRAM Conference*, ed. Jonas Landgren, Urban Nulden and Bartel Van de Walle, May 2009, http://www.iscramlive.org/ISCRAM2009/papers/Contributions/228_Technical%20and%20Cultural%20Heterogeneity%20in%20Hastily_Sigholm2009.pdf

[121] Ibid.

[122] James P. Crutchfield, "The Calculi of Emergence: Computation, Dynamics, and Induction" (SFI 94–03-016), special issue, *Proceedings of the Oji International Seminar, Complex Systems—from Complex Dynamics to Artificial Reality*, 1994, http://csc.ucdavis.edu/~cmg/papers/CalcEmerg.pdf

constraints and instantaneous forces that control a system."[123] A disrupted social system continues to maintain a high level of structure. This structure, combined with time and interaction with interrelated complex systems (technical, crisis response, environmental), effects emergent collective behavior.[124] The emergence of spontaneously ordered behavior is central to an understanding of self-organization. In addition, it is an open system response to some change and the release of self-directed energy and matter.[125] This behavior is a property of complex systems. The emergent social forces in disorder will self-organize and adapt but are limited by access to communications.

Disaster researchers have continually observed emergent behavior in social systems faced with crisis.[126] A social system in disorder will lead to emergent self-organization and adaption. Instability in a system provides energy for this behavior (in commerce, politics, and nature). It is most active at the edge of chaos where emergent and adaptive behavior is in a state that allows for growth. It is inhibited by extreme chaos or widely bounded nonlinearity—an inability to communicate.[127]

A social system in chaos represents a fracturing of the social network.[128] At that point in time (and place), it is not a functioning social system. Social energy is first directed to reestablish communication within the bounds of available technology. In the aftermath of a catastrophic event, networks and communication reform within the limits

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[123] Ibid., 2.

[124] Crutchfield, "The Calculi of Emergence;" Kauffman, *The Origins of Order*.

[125] Kauffman, *The Origins of Order*.

[126] Prince, *Catastrophe and Social Change*; Drabek, and McEntire, "Emergent Phenomena and Multi-organizational Coordination in Disasters;" Stallings, and Quarantelli, "Emergent Citizen Groups and Emergency Management;" Thomas E. Drabek, "Alternative Patterns of Decision-Making in Emergent Response Networks," *International Journal Mass Emergency and Disasters* 1, no. 2 (1983): 277–305; Enrico L. Quarantelli, *Emergent Citizen Groups in Disaster Preparedness and Recovery Activities* (Final Project Report #33) (Newark, DE: Disaster Research Center, University of Delaware, 1984); Louise K. Comfort, "Turning Conflict into Cooperation: Organizational Designs for Community Response in Disasters," *International Journal of Mental Health* 19, no. 1 (1990): 89–108; Louise K. Comfort, and Aya Okada, "Emergent Leadership in Extreme Events: A Knowledge Commons for Sustainable Communities," *International Review of Public Administration* 18, no. 1 (2013): 61–77; Russell R. Dynes, "Community Emergency Planning: False Assumptions and Inappropriate Analogies," *International Journal of Mass Emergencies and Disasters* 12, no. 2 (1994): 141–58.

[127] M. Mitchell Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos* (New York: Simon & Schuster, 1992).

[128] Luhmann, "Systemtheorie, Evolutionstheorie und Kommunikationstheorie."

of the available technology and spans are extremely localized. Communication is the required ingredient to encourage emergent self-organization.[129] The 2013 *National Response Framework* (NRF) calls for the "whole community approach"—a wholistic approach to crisis response that acknowledges the importance of engaging emergent forces.[130] An accepted assumption of crisis responders is that most of the response efforts will come from local organizations and emergent forces.

Significant literature has been devoted to emergent behavior during times of crisis by leading disaster researchers.[131] Private citizens and local officials immediately begin to reorganize after a catastrophe. Emergent social behavior in catastrophe is the localized social energy that coalesces, organizes, and responds to perceived needs.[132] As Prince noted in 1920, "The vital place of communication in society was recognized at once. It is a major influence in association, and upon it in disaster depends on the immediacy as well as the adequacy of relief."[133]

Thomas Drabek and David McEntire identify emergent groups as individuals and groups that are "volunteers, emergency workers, churches, businesses, government agencies and other concerned or curious parties."[134] These forces are an essential component to a successful response.[135] Furthermore, emergent groups are not constrained (or organized) by traditional crisis response systems. These reflexive self-organizational and adaptive forces respond to immediate crisis and, in many instances, are

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[129] Prigogine, Stengers, and Toffler, *Order out of Chaos*; 189.

[130] U.S. Department of Homeland Security, *National Response Framework*, 3.

[131] Prince, *Catastrophe and Social Change*; Quarantelli, *Emergent Citizen Groups in Disaster Preparedness*; Fritz, and Mathewson, *Convergence Behavior in Disasters*; Fritz, "Disasters;" Stallings, and Quarantelli, "Emergent Citizen Groups and Emergency Management."

[132] Quarantelli, *Emergent Citizen Groups in Disaster Preparedness*; Stallings, and Quarantelli, "Emergent Citizen Groups and Emergency Management."

[133] Prince, *Catastrophe and Social Change*, 26.

[134] Drabek, and McEntire, "Emergent Phenomena and Multi-organizational Coordination."

[135] U.S. Department of Homeland Security, *National Response Framework*; Stallings, and. Quarantelli, "Emergent Citizen Groups and Emergency Management;" Louise K. Comfort, *Self-Organization in Disaster Response: The Great Hanshin, Japan Earthquake of January 17, 1995* (Boulder, CO: Natural Hazards Center, University of Colorado, Boulder, 1995), http://www.colorado.edu/hazards/research/qr/qr78/qr78.html; Erik Auf der Heide, *Disaster Response: Principles of Preparation and Coordination* (St. Louis: MO: CV Mosby Co., 1989);

improvements to response and organization.[136] Within disorder there is order,[137] and the existing social structures are an attractor.[138] They do represent significant challenges to organizing, coordinating and logistics.[139] Furthermore, the pace of self-organization is limited by communication.[140] Without a functioning communications system, the small ad-hoc emergent groups are isolated and unorganized. These uncoordinated groups represent significant potential, but they require assistance from outside. This is the intersection of emergence and convergent forces.

Outside of the impacted areas, the extended social systems respond to a catastrophic event. This response represents a form of movement towards a central gravitational field (the affected communities) from outside the affected region.[141] This has been a common characteristic of crisis response to affected communities that have insufficient resources.[142]

Fritz and Mathewson identify the forms of convergence:

- personal—the actual movement of persons (official and voluntary)
- informational—movement or transmission of data
- material—movement of supplies and equipment[143]

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[136] Comfort, *Self-Organization in Disaster Response*; Comfort, "Self-Organization in Complex Systems." Neil Britton, *Anticipating the Unexpected: Is the Bureaucracy Able to Come to the Dance?* (Working paper no. 1, Disaster Management Studies Centre, Cumberland College of Health Sciences, Sydney, Australia, 1989), 15.

[137] Kiel, "Chaos Theory and Disaster Response Management;" Pine, "The Contributions of Management Theory and Practice to Emergency Management."

[138] Dynes, "Community Emergency Planning."

[139] Enrico L. Quarantelli, "Disaster Studies: An Historical Analysis of the Influences of Basic Sociology and Applied Use of Research Done in the Last 35 Years" (paper presented at the Symposium on Social Structure and Disaster, College of William and Mary, Williamsburg VA, 1986); Auf der Heide, *Disaster Response*.

[140] Comfort, *Self-Organization in Disaster Response*.

[141] Fritz, and Mathewson, *Convergence Behavior in Disasters*.

[142] Prince, *Catastrophe and Social Change*; Clifford Oliver, *Catastrophic Disaster Planning and Response* (Washington, DC: CRC Press, 2010).

[143] Fritz, and Mathewson, *Convergence Behavior in Disasters*.

Crisis management needs to content with both positive and negative impacts of social response.[144] The perception of the event's impact will relate to the size and complexity of the external convergence.[145]

Fritz and Mathewson note the importance of communication to successfully integrate convergent forces.[146] Informational convergence represents the general need to understand the situation. Examples of this can be offers of assistance, formal inquiries, media convergence, and expressions of concern or the formation of common operating picture (COP). However, this does create challenges, such as overloading of communication facilities.[147] Fritz and Mathewson note: "The most immediate and crucial need in disasters is "speedy, accurate, authoritative information, coordinated and adapted to the specific needs of various groups concerned with the."[148] They observe:

> The general picture that emerges from an analysis of numerous disaster reports is a mosaic of formal and informal efforts to reconnoiter and assess the situation, conflicting initial reports, gross ambiguities and inaccuracies in both the word-of-mouth and mass media announcements, and lack of coordination among the various information-gathering, evaluating and disseminating agencies.[149]

Fritz and Mathewson conducted the study during a period of relatively simplistic communications options, yet these observations are still relevant.[150] They recommend the creation of an informational-specialist corps that would rapidly deploy, set-up forward operations posts in the affected communities, and focus on the collection, coordination, and dissemination of information. This corps would also have the personnel to handle information and communication technology (ICT) challenges. During operations, this would integrate with local personnel to promote efficient operations.[151] This

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144 Oliver, *Catastrophic Disaster Planning and Response*, 151.

145 Ibid.

146 Fritz, and Mathewson, *Convergence Behavior in Disasters*.

147 Fritz, and Mathewson, *Convergence Behavior in Disasters*, 15; Auf der Heide, *Disaster Response*.

148 Fritz, and Mathewson, *Convergence Behavior in Disasters*, 61–62.

149 Ibid., 62.

150 Ibid.

151 Ibid., 66.

recommendation is remarkably similar to the rapid technology assessment teams (RTAT),[152] or the UN Fast Information Technology and Telecommunication Emergency and Support Team (FITTEST) units.

Emergent and convergent forces are a constant in disaster response. The challenge is to coordinate these forces in the shortest amount of time. The common problem is the lack of connectivity and information management. Additionally, communication can alter the balance of the system. The group with access to communication will achieve dominance. Furthermore, communication access will affect the response since it is impossible with certainty to determine if that group is well led and or has the capabilities to provide services. A power shift among the emergent groups can have unforeseen consequences and lead to mismanagement.

First responders play a central role in the intersection between emergent and convergent forces. The first response personnel represent the local government and serve as a bridge; however, the local first-response communities are often victims themselves. Stallings and Quarantelli note that during a crisis, social roles often change.[153] A fire chief could be responsible for emergency housing, or a local elected official could assume responsibilities that are unforeseen. These adaptions of roles are a product of self-organization forces.[154]

The *National Response Framework* (NRF)[155] and disaster researchers are in agreement on the whole community approach: that emergent forces represent the energy

[152] Brian Steckler, "Rapid Technology Assessment Teams (RTAT)" (unpublished manuscript, Naval Postgraduate School, August 2012).

[153] Stallings, and Quarantelli, "Emergent Citizen Groups and Emergency Management."

[154] Kreps, and Bosworth, "Disaster, Organizing, and Role Enactment."

[155] U.S. Department of Homeland Security, *National Response Framework*.

and manpower that is essential to successful response.[156] This force requires communication to be effective. A primary objective for convergent forces is to provide the ICT support.

F. INFORMATION REVOLUTION

Information and communication technology is experiencing exponential transformative changes. The methods and power to connect, share information, process data, and create knowledge is accelerating and growing in complexity. It must be acknowledged that the Information Revolution is a component of crisis response environment that represents transformational changes, momentous challenges, novel vulnerabilities, and potential unimagined solutions. The changes are so rapid and powerful that crisis responders must acknowledge this challenge with regards to the organization and management.[157] Management systems that are based primarily on paper-based processes or an overwhelming reliance on push-to-talk radios do not leverage the potential power of advanced ICT.

Communication failures during crisis response are a common theme that has not been abated with the advent of advanced information and communication

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[156] Stallings, and Quarantelli, "Emergent Citizen Groups and Emergency Management;" Auf der Heide, *Disaster Response*; Drabek, and McEntire, "Emergent Phenomena and Multi-organizational Coordination;" Quarantelli, *Emergent Citizen Groups in Disaster Preparedness and Recovery Activities*; U.S. Department of Homeland Security, *National Incident Management System* (Washington, DC: Department of Homeland Security, 2008), http://www.fema.gov/pdf/emergency/nims/NIMS_core.pdf; Russell R. Dynes, *Governmental Systems for Disaster Management* (preliminary paper no. 300, Disaster Research Center, University of Delaware, Newark, NJ, 2000); Gary A. Kreps, ed., *Social Structure and Disaster* (Newark, NJ: University of Delaware Press, 1989).

[157] David S. Alberts, and Richard E. Hayes, *Power to the Edge Command and Control in the Information Age* (Washington, DC: Command and Control Research Program, 2003), http://www.dodccrp.org/files/Alberts_Power.pdf

technologies.[158] Though communication is a constant problem, the rate of technical change in:

> information technologies such as networks, mobile and distributed systems, databases, data analysis and mining, image processing, security, decision-support tools, etc., are incorporated in the research activities with the objective of revolutionize the ability to gather, manage, analyze and disseminate information in crisis response.[159]

According to Barabási, "Fuelled by cheap sensors and high-throughput technologies, the data explosion that we witness today, from social media to cell biology, is offering unparalleled opportunities to document the inner workings of many complex systems."[160] Technological and social communications are not static but dynamic, interrelated open systems that require the crisis response community to challenge long-established management systems. The environment of change represented by advancement of communication systems is integral to the understanding of modern communications and social systems.

G. DISASTER RESPONSE MODELS

The focus of this thesis is the catastrophic event, and it is assumed that this type of event would require federal response. The response follows mandated management and planning doctrines that shape domestic crisis response. The first case study on Hurricane Katrina focuses on the failure to implement a comprehensive communication

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[158] Prince, *Catastrophe and Social Change*; Fritz, and Mathewson, *Convergence Behavior in Disasters*; Moynihan, "The Network of Governance of Crisis Response;" Russell R. Dynes, and Enrico L. Quarantelli, *Organization Communications and Decision Making in Crisis* (Miscellaneous report no. 18, Ohio State University: Disaster Research Center, Columbus, OH, 1976); Louise K. Comfort, and Thomas W. Haase, "Communication, Coherence, and Collective Action: The Impact of Hurricane Katrina on Communications Infrastructure," *Public Works Management and Policy* 11, no. 1 (2006): 1–16; Thomas E. Drabek, "Managing the Emergency Response," special issue, *Public Administration Review*, 45 (1985): 85–92; Louise K. Comfort, Brian A. Chalfant, Jee E. Song, Mengyao Chen, and Brian Colella, "Managing Information Processes in Disaster Events: The Impact of Superstorm Sandy on Business Organizations," in *Proceedings of the 11th International ISCRAM Conference*, University Park, PA, 2014, 310–332, http://www.iscramlive.org/ISCRAM2014/papers/p94.pdf

[159] Nadia Nouali et al., "Using Information Technology for Enhancing Disaster Management," in *Congrès National des Télécommunications et leurs Applications* (Algiers: University of Bejaia, Algeria, 2009), http://www.scribd.com/doc/16654082/Using-Information-Technology-for-Enhancing-Disaster-Management#scribd, 5.

[160] Barabási, "The Network Takeover."

strategy within the framework of the *National Response Plan*. The second case study compares an international response during the earthquake in Haiti. An international response, such as the one in Haiti, follows different protocols and management policies. The commonality is a failure to rapidly reestablish communications and the impact on response.

U.S. policies define the relationships between governmental agencies (federal, state, local, and tribal), private industries, and citizens. The central documents for this research are the *National Response Plan* (NRP) or *National Response Framework* (NRF) (after Katrina), *National Incident Management System* (NIMS),[161] *Incident Command System* (ICS) and the *Emergency Support Functions: (ESF) #2—Communications Annex* and *ESF #5 Emergency Management*. These are supported by considerable live official sources that illustrate programs, efforts and policies on local, state and the federal levels.

The policy and planning documentation has been through significant revisions, notably in 2008 and 2013. The 2008 revision represents a response to the perceived failures during Hurricane Katrina. The communication and information are elevated but the management resources are still fragmented. The 2013 revision has the benefit of experiences drawn upon from the Hurricane Sandy response. The FEMA and DHS archives have been invaluable resources of official documentation and policy statements. Tracking the evolution of these planning and policy documents demonstrates three points of understanding in time:

- 2004—*Lack of understanding* of the communication process. The expectation that the introduction of ICS would create an environment that standardized management and communication processes. The timing of the changes to national response (and resulting unfamiliarity), the political environment, and the scope of Katrina created a communications disaster that impeded effective response.
- 2008—*The reaction* to Katrina saw increased focus on communication but an overall strategy is missing. The *National Emergency Communications Plan* (NECP) focuses primarily on interoperability; this is not a systems

[161] Department of Homeland Security, *National Incident Management System*.

approach.[162] The resources and authority continue to be fragmented within ICS and ESF.

- 2013—*The continuation* of 2008 policies after the experiences of Hurricane Sandy. As of December 2014 the NRF, NECP and the ESF have been updated; NIMS has not.

Hurricane Katrina examines the domestic crisis response strategy and failure to develop and execute a communications strategy. The converging forces are in the best position after impact to begin the process of reestablishing a communications system. These forces can arrive with trained, organized personnel and resource. These fresh forces would begin the process of assessment and restoring connectivity as the local responders and emergent forces are organizing. The official reporting proved to be essential source for the study, these (but not limited to) include: *Hurricane Katrina: A Nation Still Unprepared* (US Senate, 2006),[163] *A Failure of Initiative: The Final Report of the Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina* (US House of Representatives, 2006)[164] and *The to Hurricane Katrina: Lessons* (White House, 2006).[165]

After Hurricane Katrina the *National Response Plan* (NFP) was updated to correct the mishandling of communication (US DHS NFP, 2004; U.S. DHS NRF, 2008).[166] The plans take into account the importance of communication without establishing a comprehensive strategy for its reestablishment. It is important to compare

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[162] U.S. Department of Homeland Security, *National Emergency Communications Plan* (Washington, DC: Department of Homeland Security, 2008), https://www.dhs.gov/xlibrary/assets/national_emergency_communications_plan.pdf

[163] *Hurricane Katrina: A Nation Still Unprepared: Special Report of the Committee on Homeland Security and Governmental Affairs United States Senate Together with Additional Views*, 109th Cong. (2006), http://www.gpo.gov/fdsys/pkg/CRPT-109srpt322/pdf/CRPT-109srpt322.pdf

[164] *A Failure of Initiative: The Final Report of the Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina*, 109th Cong., (2006), (109), http://www.gpo.gov/fdsys/pkg/CRPT-109hrpt377/html/CRPT-109hrpt377.htm

[165] White House, *The Federal Response to Hurricane Katrina: Lessons Learned* (Washington, DC: Government Printing Office, 2006).

[166] U.S. Department of Homeland Security, *National Response Framework*; U.S. Department of Homeland Security, *National Response Plan* (Washington, DC: Department of Homeland Security, 2004), https://it.ojp.gov/fusioncenterguidelines/NRPbaseplan.pdf

efforts and changes to the *National Response Framework* since Hurricane Katrina to assess the mandated improvements that relate to communication and crisis response.

The second case study is an examination of international response to a catastrophic event (the earthquake in Haiti). The UN response model has some core similarities with the U.S. model, namely the emergency support functions are analogous to the UN Cluster System. However, the UN system does not rely on ICS and the overall management of the system is the responsibility of the United Nations Office for the Coordination of Humanitarian Aid (OCHA). A major international crisis response has far greater obstacles to successful communications than those presented solely within the U.S.

The UN response system has devoted greater resources to communication and information management, but still the result was a communications disaster in Haiti. The problems that manifested during Haiti were a result of underestimatingof the rapidly advancing technical environment. The amounts of data and the inability to manage the data overwhelmed the UN communications efforts. Furthermore, the UN response did not have a practical communication strategy and emergent forces were not effectively networked in a timely manner. The response to Haiti represented a failure of communication due to insufficient appreciation of the technical environment, the greater need for increased ICT resources, and the understanding that communication and information management are a first-order priority.

H. HASTILY FORMED NETWORKS

Historically, converging force have been unable to quickly restore communications, and the selected case studies reflect the effect on response performance. The urgent need for communications, sharing of information, and restoring order require the converging forces make a rapid restoration of a communications a primary strategic objective. The hastily formed network concept is method to address communications that has been developed at the Naval Postgraduate School (NPS).

During the chaotic response, communication is a primal need that crisis responders will achieve by any means. The need to communicate will drive entities to

independently begin to search for ad-hoc technological solutions. The DHS performance review of FEMA during Hurricane Katrina named "unreliable communication systems" and FEMA's inability to adequately restore basic communications to wide areas within the effected zone as a key responsibility failure.[167]

NPS developed the hastily formed network (HFN) concept and created a center devoted to improving and enhancing communication, cooperation, and collaboration at future disasters. An HFN is a rapidly established network of people from different communities who are working together in a shared conversation space in which they plan, commit to, and execute actions, to fulfill a large, urgent mission.[168]

Peter Denning explains that the HFN concept "is more than a set of organizations using advanced networking technology (Denning 2006 pg. 17).[169] The HFN concept addresses communications networks aimed at rapidly connecting the unconnected. The first step is creating links between people, communities, and organizations to improve the ability to share knowledge, develop a common operating picture, "access options, plan responses, decide, commit, act and coordinate.[170] The key elements are the technical solutions to create a communications network and the manner (the system) in which they interact.[171]

After the HFN-team deployment in Haiti, Brian Steckler used experiences in catastrophic environments to formulate the rapid technology assessment team (RTAT) concept.[172] He proposed the use of rapidly deployable, "small, nimble, multi-organizational, multi-national integrated teams of specialists in key ICT areas (wireless data communications, voice communications, radio technologies, power, information

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[167] U.S. Department of Homeland Security, *A Performance Review of FEMA's Disaster Management Activities in Response to Hurricane Katrina* (Washington, DC: U.S. Department of Homeland Security Office of Inspections and Special Reviews, 2006), 77–78.

[168] Peter J. Denning, "Hastily Formed Networks," *Communications of the ACM* 49, no. 4 (2006): 16–17.

[169] Ibid., 17.

[170] Ibid., 16.

[171] Ibid.

[172] Steckler, "Rapid Technology Assessment Teams (RTAT)."

sharing, social networking, etc.)."[173] The teams would provide quality assessment of the information and communication technology power situation by experts and distribute this *reliable*, *trusted* information.[174] Additionally, these teams represent a method to control chaos through the introduction of small perturbations. The theory is that small technical teams that are focused on ICT reconnaissance and assisting an aggressive restoration of communication represents small changes that will have nonlinear effects on the chaotic environment. The use of these teams will require careful pre-planning and extensive feedback once committed. This first wave begins the reestablishment of a network working from identified centers of organization and linking adjacent nodes (organizing emergent groups). These are the beginnings of an overall communications strategy.

The advances in ICT have created new challenges for crisis response and new possibilities in organizational structure.[175] Though response community acknowledges the importance of communication, little has been done to change the relationship of communication objectives within the framework of domestic management models. Karlene Roberts's research into high reliability organizations (HROs) identifies dynamic complex socio-technological systems that require a functioning communication and a learning process loop.[176] Crisis response systems strive to utilize advanced technology. The issue is that domestic crisis response (following the ICS model) utilizes ICT in support of operations, planning, logistic, and administration sections. There needs to be a change in organization and management models that organizes the information and communications efforts into a group or branch with authority, resources, and independence to pursue a comprehensive communication strategy.

The use of HFN and RTATs represent a commitment to a communications strategic objective: the reestablishment of disrupted networks. The next step is to support and manage the evolution of the growing HFN. The initial networks will be small and

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[173] Ibid., 2.

[174] Ibid.

[175] Törnqvist, Sigholm, and Nadjm-Tehrani, "Hastily Formed Networks for Disaster Response."

[176] Karlene H. Roberts, *New Challenges to Understanding Organizations* (New York: Macmillan Publishing Company, 1993).

weak but represent and engagement of the converging forces to the affected communities. The goal is to quickly provide networks that will foster self-organization and adaption by emergent forces and the integration of converging forces. The converging forces are in the position with resources and technical expertise. The missing ingredient is a plan that recognizes the importance and independence of ICT objectives. This importance is reflected by an organizational change that makes ICT related services a section within ICS equal to operations, planning, logistics, and administration (and a part of the general staff). A new section acknowledges that some communications strategic objectives are not just to support other sections. The communications strategy will focus on creating, growing, and managing a hastily formed network using advanced ICT.

III. RESEARCH DESIGN

The first step in this research was to define the context. The words: catastrophe, complexity, chaos, and systems are so commonly used in crisis research that the meaning can become opaque. Establishing a context sets clearer boundaries for the case studies. The research required a substantial survey of the literature that defines the event and the concepts. As would be expected, any inquiry into complexity reveals the interrelation of systems and the role communications plays in self-organization. The review of the literature provided the overall framework: catastrophe is a severe disruption to a large segment of socio-technical systems, communications is a foundational system for self-organizing, and effective response requires restoration of communication systems.

The research for this thesis relies on two case studies (Hurricane Katrina and earthquake in Haiti 2010). These two studies meet the environmental criteria of a catastrophic event complicated by a near total failure of the communications infrastructure. The case studies offer contrasting crisis response models (domestic and international). Though the approach to crisis response is very different, the commonality is a failure to restore a communications system.

The comparative case study method was selected to allow the careful consideration of the qualitative and quantitative data. The studies serve to define the phenomenon in context.[177] The studies represent a narrative of the effects of a catastrophe on complex socio-technical systems, crisis response systems, and communications systems. The overarching consideration is the communications situation presented to converging forces and the efforts made to improve the situation during the initial chaotic period.

The two studies were selected based on several criteria. Catastrophic events are not regularly occurring; thus, the data set is small.

[177] Robert K. Yin, "The Case Study Crisis: Some Answers," *Administrative Science Quarterly* 26, no. 1 (1981): 58–65.

Case studies criteria:

- Hurricane Katrina and earthquake in Haiti (criteria):
  - Both events had access to modern networking technology
  - Near total failure of the communications infrastructure
  - Complex emergency response from substantial numbers of diverse agencies, groups, volunteer entities, non-governmental organizations (NGO)
  - Technical challenges comparable
  - Well-documented, official reports, after action review (AAR), lessons learned (LL)
  - Naval Postgraduate School (NPS) Hastily Formed Network (HFN) deployment
  - Different crisis response organizational framework

There has not been a widely embraced or successful solution to rapid reestablishment of communications in the initial chaotic stage of a catastrophic event. The differing framework allows the research to define common problems that are not linked to policy or regional procedures. The deployment of NPS HFN team provides essential data and observations from a specialized unit that is solely tasked with rapid restoration of ICT.

The methodologies used to research the case studies are:

- Assess after action reviews, lessons learned documents, articles, and academic peer-reviewed theses related to the two case studies.
- Examine official documentation for domestic crisis response as it relates to communication strategy
- Determine efficacy of HFN model using deployment reports, after action reviews, and industry related articles.
- Conduct comprehensive review network data from studies on Hurricane Katrina.

The Hurricane Katrina network was evaluated using different data sources utilizing different collection methods (see Appendix A). Three studies pertaining to Hurricane Katrina serve as a basis of the research. The data from three studies were

examined using social network analysis (SNA) tools to confirm the results and to examine specific aspects of the crisis response networks. The studies are:

- Carter Butts, Ryan Acton, and Christopher Marcum's "Interorganizational Collaboration in the Hurricane Katrina Response" (data publicly available)[178]
- Louise K. Comfort at the University of Pittsburgh, Center for Disaster Management[179]
- Naim Kapucu at the Department of Public Administration, University of Central Florida[180]

The Hurricane Katrina data was kindly provided by the University of Pittsburgh and the University of Central Florida, and the study by Butts, Acton, and Marcum was publically available.

Analysis of the Haiti response network uses studies conducted by the University of Pittsburgh, Center for Disaster Management. Additionally, the research of the Haiti networks was confined to an analysis of the network statistics. This analysis found network evolution and structural similarities.

This framework represents the guiding principles for operations. One of the goals of the thesis is to provide recommendations for future domestic crisis response. For that reason, the research into the domestic crisis response official and mandated organization is probed in a vigorous manner. The UN response to Haiti allows the examination of contrasting organizational and management styles within a similar context and with similar results (as they apply to the rapid establishment of communications systems).

The use of the case studies and empirical data allows the building of a theory.[181] The method by this research is a combination of historic narrative of the relevant facts and empirical data analysis using SNA to reveal common patterns in crisis response

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[178] Carter T. Butts, Ryan M. Acton, and Christopher M. Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response," *Journal of Social Structures* 13 (February 2012): 1–36, https://www.cmu.edu/joss/content/articles/volume13/ButtsActonMarcum.pdf

[179] Louise F. Comfort, email to author, August 11, 2014.

[180] Nail Kapucu, email to author, September 5, 2014.

[181] Kathleen M. Eisenhardt, and Melissa E. Graebner, "Theory Building from Cases: Opportunities and Challenges," *Academy of Management Journal* 50, no. 1 (2007): 25–32.

networks. The emergent theory is that chaos can be controlled (perturbations and alterations of orbits) by crisis response. Crisis response requires the creation and implementation of a new communication systems strategy, altering ICS to pursue that strategy and utilizing hastily formed network concepts as well as rapid technology assessment and technology teams.

A goal of this research is to define a serious common problem in crisis response. The examination of shared failures and successes to provide solutions and smart practices for future disaster response. The importance is obvious: greater efficiency in crisis response to limit or decrease humanitarian suffering and economic loss.

IV. HURRICANE KATRINA

"By any measure, Hurricane Katrina was a national catastrophe."[182]

A. INTRODUCTION

In 2005, Hurricane Katrina struck the Gulf Coast with catastrophic consequences, and one of the largest natural disasters in contemporary United States history. The storm destroyed much of New Orleans. The crisis response covered a vast area containing approximately 1.5 million people in the Gulf Coast. The most essential response objective was the rapid restoration of a communications system. According to Comfort and Haase, "The task of mobilizing a coherent, coordinated warning and response system for this catastrophic storm was massively complex."[183] The vital importance of communications and their effects on response is a constant theme running through disaster research.[184] The quality of communication systems in extreme crisis has a direct correlation to successful complex response. This was evident "in the halting intergovernmental response to Hurricane Katrina, beginning on August 23, 2005."[185] The lack of a functioning communication system created massive problems for decision makers, led to uncoordinated response, and handicapped self-organization within the affected communities.

This case study examines the impact of Hurricane Katrina on the Gulf states and the response, focusing on the inability to reestablish communication as the leading cause

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[182] White House, *The Federal Response to Hurricane Katrina*, 9.

[183] Comfort and Haase, "Communication, Coherence, and Collective Action," 2.

[184] Kreps, and Bosworth, "Disaster, Organizing, and Role Enactment;" Prince, *Catastrophe and Social Change*; Fritz, and Mathewson, *Convergence Behavior in Disasters*; Enrico L. Quarantelli, "Disaster Crisis Management," presented at International Conference on Industrial Crisis Management in New York City, September 1986, http://udspace.udel.edu/bitstream/handle/19716/487/PP113.pdf?sequence=3; William L. Waugh, "Public Administration, Emergency Management, and Disaster Policy," in *Disciplines, Disasters and Emergency Management*, ed. David A McEntire (Washington, DC: Federal Emergency Management Agency, 2002), https://training.fema.gov/hiedu/docs/emt/disciplines,%20disasters%20and%20em%20txtbk%20-%20table%20of%20contents.doc; Louise K. Comfort, *Shared Risk: Complex Systems in Seismic Response* (New York: Pergamon, 1999).

[185] Comfort and Haase, "Communication, Coherence, and Collective Action," 1.

for the failure. The response lacked an overarching communications strategy and the communications was considered a support function rather than a strategic imperative.

The response to Katrina demonstrated a lack of preparation and emphasis on a communications strategy, the inability to rapidly reestablish communications, create a workable network, or collect incoming data within an efficient information management system. Without useful information, the converging forces were unable to act in a flexible or agile manner, information was not shared, which affected decision making, and as a result, the affected communities were isolated.

B. IMPACT

The titles of two major congressional reports clearly captures the general opinion of the response: The titles of the two congressional reports clearly captures the general opinion of the response: Select House Committee, "A Failure of Initiative"[186] and the Senate Committee on Homeland Security and Governmental Affairs, "A Nation Still Unprepared."[187] These reports have a common theme: that communications posed a serious problem both during the storm and in its immediate aftermath.[188] Without communication, there was very little overall direction for the responding forces, self-organization of the affected population was severely handicapped, and the chaos of the response phase was extended. The loss of communication also created an isolated response during which the responders were unable to define the immediate needs and goals without accurate, timely, and verifiable information. According to Pijnenburg and Van Duin, "Most of the time crisis situations turn out to be, to a large extent, information and communication crises."[189]

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[186] *A Failure of Initiative*. Make sure this is in italics and so is a nation unprepared (in text)

[187] *Hurricane Katrina: A Nation Still Unprepared*.

[188] *A Failure of Initiative*; *Hurricane Katrina: A Nation Still Unprepared*; White House, *The Federal Response to Hurricane Katrina*; U.S. Government Accountability Office, *Hurricane Katrina GAO's Preliminary Observations Regarding Preparedness, Response, and Recovery* (Washington, DC: U.S. Government Accountability Office, 2006).

[189] Bert Pijnenburg, and Menno van Duin, "The Zeebrugge Ferry Disaster: Elements of a Communication and Information Processes Scenario," in *Crisis Management and Decision Making: Simulation Oriented Scenarios*, ed. Uriel Rosenthal, and Bert Pijnenburg (45–73) (Dordrecht, Netherlands: Kluwer Academic, 1991), 70.

In the *Federal Response to Hurricane Katrina: Lessons Learned*, the impact of the storm created unprecedented needs and challenges. "Hurricane Katrina impacted nearly 93,000 square miles across 138 parishes and counties."[190] Official reports are very critical of the response on all levels and called for changes to national crisis response.[191] The physical effects of the storm were severe (see Table 1). The misery was compounded by a disaster response that was characterized as "failure of government at all levels to plan, prepare for, and respond aggressively to the storm. These failures were not just conspicuous; they were pervasive."[192] The U.S. Senate's report went on, noting, "the suffering that continued in the days and weeks after the storm passed did not happen in a vacuum; instead, it continued longer than it should have."[193] In addition, the report consistently identified an inability to communicate or rapidly reestablish communication as the central factor in the response failure.

Table 1. Hurricane Katrina Damage Assessment[194]

Storm related deaths	1,577
Homes destroyed	300,000
Land area damaged by Hurricane Katrina	90,000 sq. miles
Estimated economic loss related to Hurricane Katrina	$125–$150 billion
Electric customers, all types, left without power by storm	1.7 million
Customers without phone service	3 million
Cellular towers damage (out of 7,000)	1,000

[190] White House, *The Federal Response to Hurricane Katrina*, 5.

[191] White House, *The Federal Response to Hurricane Katrina*; *A Failure of Initiative*; *Hurricane Katrina: A Nation Still Unprepared*; Department of Homeland Security, *A Performance Review of FEMA's Disaster Management*.

[192] *Hurricane Katrina: A Nation Still Unprepared*, 2.

[193] Ibid., 2.

[194] Ibid.

Much of the communications systems infrastructure was destroyed, negatively affecting response, severely limiting situational awareness, and contributing to severe problems communicating operational plans or engaging local response.[195] According to a White House report, "Almost three million phone lines were knocked out, telephone switching centers were seriously damaged."[196] This lead to the collapse of many 911 call centers.[197] Wireless communications were also affected, approximately 1,477 cell towers were out of service, and widespread power loss left few places to charge the phones.[198] The damaged included most radio and television as well as first responders dispatch systems.[199] Many emergency operation centers (EOC) were rendered unusable due to flooding or other damage, eliminating a base for command operations and resulting in poor coordination and wasted time as responders looked for new locations.

The hurricane impact and flooding, combined with massive infrastructure failure, caused the social disruption that left the survivors, isolated, disorganized, and in chaos. This was an environment that was extremely chaotic and complex. Convergent forces have the greatest influence on reestablishing a communications system, bringing trained personnel and resources from outside the impacted zones. The Katrina response was a continuation of crisis management mistakes of devoting insufficient resources and inadequate pre-planning to crisis response communications.

C. CONTEXT

Donald Moynihan clearly frames the situation leading up to Hurricane Katrina catastrophe as the "first major disaster that took place after the introduction of new crisis management policies, and represents their first critical test."[200] At the time, DHS and FEMA where going through a major reorganization. The *National Response Plan* (NRP)

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[195] White House, *The Federal Response to Hurricane Katrina*, 34.

[196] Ibid.

[197] Ibid.

[198] Ibid.

[199] Ibid.

[200] Donald P. Moynihan, "What Makes Hierarchical Networks Succeed? Evidence from Hurricane Katrina" (paper presented at the annual meeting of the Association of Public Policy and Management, November, 2006, Madison, WI), http://minds.wisconsin.edu/handle/1793/37586?show=full, 3.

and the emergency support functions (ESF) were newly written (published in 2004 and 2005 respectively),[201] and the *Catastrophic Incident Annex* (NRP-CIA)[202] had not yet been published. Misunderstanding and unfamiliarity lead to conflicts and organizational confusion.[203] The U.S. Senate report found the National Communications System (a DHS agency), primarily responsible for providing communications support to first responders during disasters, had no plans to do so.[204]

The failure can be traced to the dysfunctional system that inhibited the creation of response networks and to an inability to restore social stability. At the foundation was a failure to understand the dependence of socio-technical systems on a functioning communications system. The NRP focus was on the organizational responsibilities and management of a complex response system.[205] The expectation is that the organizational system will generate networks and relationships across clearly defined lines. In a stable state environment, this assumption would be difficult to support; however, during catastrophe, it has proved to be a major response gap.

D. DISCONNECTION

According to the *A Failure of Initiative*, "The Katrina network was so large that there was a failure to fully comprehend all of the actors actually involved."[206] According to NOAA, "entire coastal communities were obliterated, some left with little more than the foundations upon which homes, businesses, government facilities, and other historical buildings once stood."[207] A large number of people either failed or were unable to evacuate. These victims presented the response with an enormously complex task of

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[201] Department of Homeland Security, *National Response Plan* (2004).

[202] Federal Emergency Management Agency, *Catastrophic Incident Annex* (Washington, DC: Federal Emergency Management Agency, 2008), http://www.fema.gov/national-preparedness-resource-library

[203] *Hurricane Katrina: A Nation Still Unprepared*, 12.

[204] *Hurricane Katrina: A Nation Still Unprepared*, 15; Department of Homeland Security, *National Response Plan*; Federal Emergency Management Agency, *Emergency Support Function #2: Communications Annex*, 2004, http://www.fema.gov/pdf/emergency/nrf/nrf-esf-02.pdf

[205] Department of Homeland Security, *National Response Plan*; Department of Homeland Security, *National Incident Management System*.

[206] *A Failure of Initiative*.

[207] White House, *The Federal Response to Hurricane Katrina*.

providing rescue, relief, and support. The *Federal Response to Hurricane Katrina* notes that DHS reported the communications infrastructure in Biloxi and Gulfport as "non-existent."[208] Additionally, the governor of Mississippi observed, "My head of the National Guard might as well have been a Civil War general."[209] Each affected community lacking communication became a disconnected and isolated social subsystem.

The U.S. House of Representatives official report notes, "Massive communications damage and a failure to adequately plan for alternatives impaired response efforts, command and control, and situational awareness."[210] According to Patrick Lagadec, the contemporary "environment demands dynamic linkages, fluidity and speed, shared information, and collective confidence."[211] Private citizens perform the majority of crisis response, and they do not respond well to management styles that rely on chains of command or hierarchical command structures. This force is not an official part of the national crisis response system and interaction with this essential force is delicate.[212] The data from the response demonstrates that the converging forces were unable to rapidly reestablish communications or effectively engage with localized response. This posed a significant obstacle for self-organization of the affected communities. The *A Failure of Initiative* report states, "The poor situational awareness, and its resulting effect on command and control, contributed to the negative effects of inaccurate or unsubstantiated media reports because public officials lacked the facts to address what the media reported."[213]

The U.S. Senate report notes that some private-sector entities were successful dealing with communications.[214] The Wal-Mart retail merchandise chain used lessons learned from previous hurricanes to focus on ICT crisis strategy. Wal-Mart Chief

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[208] Ibid.

[209] *Hurricane Katrina: A Nation Still Unprepared*, 287.

[210] *A Failure of Initiative*, 3.

[211] Lagadec, "A New Cosmology of Risks and Crises," 9.

[212] Ibid.

[213] *A Failure of Initiative*, 163.

[214] *Hurricane Katrina: A Nation Still Unprepared*.

Information Officer (CIO) Linda Dillman led an aggressive ICT effort to prepare the company for crisis.[215] This included building a Wal-Mart EOC, active participation in employees in the communication process, and the creation of robust assessment tools. Wal-Mart was able to maintain or restore communication with store within the affected area and provide essential services. Senator Joe Lieberman testified that Wal-Mart became distribution points for emergency resources.[216] These stores were able to continue (and expand) operations because Wal-Mart emphasized communication.

The converging forces had significant communications assets. FEMA supports five mobile emergency response support (MERS) detachments. These units are designed for rapid deployment to provide crisis communications and operational and logistical support. The five MERS detachments serve the 10 FEMA regions. Additionally, MERS detachment is capable of serving a large field office and distributing smaller units to several field sites. Finally, MERS rapid response teams have the ability to deliver support through satellite terminals, cellular telephones, and computers.

Only two MERS detachments were activated before Hurricane Katrina made landfall.[217] These two detachments were inadequate. The convergent forces had not prepared for the massive disruption of the communication infrastructure. The primary communication method for Mississippi Emergency Management Agency (MEMA) with the affected counties was solely through satellite phones and radios.[218] A MERS detachment responded to the state EOC in Jackson, Mississippi to provide satellite communications systems;[219] "However, despite the presence of MERS and hand-held satellite phones in all of the affected counties' EOCs, the Federal Coordinating Officer

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[215] Laurie Sullivan, "Wal-Mart CIO: Hurricane Charlie Paved way for Katrina Response," *Information Week*, September 19, 2005, accessed August 11, 2014, http://www.informationweek.com/wal-mart-cio-hurricane-charlie-paved-way-for-katrina-response/d/d-id/1036198?

[216] *Hurricane Katrina: What Can Government Learn from the Private Sector's Response? Hearing before the Committee on Homeland Security Affairs United States Senate*, 109th Cong. (2005), (testimony of Joe Lieberman) http://www.gpo.gov/fdsys/pkg/CHRG-109shrg24932/html/CHRG-109shrg24932.htm

[217] White House, *The Federal Response to Hurricane Katrina*.

[218] *A Failure of Initiative*, 164.

[219] Ibid., 165.

for Mississippi, Bill Carwile, testified that communications capabilities were far short of what was needed to be effective."[220]

Unfortunately, the MERS units were not aggressively engaged. Without an overall communications strategy, these units supported command, operations, logistics, and administrative functions. The detachments had significant capabilities, but they were insufficiently deployed and then used only as support. The Hurricane Pam exercise had recommended rapidly deployable assessment teams.[221] This concept would have deployed ICT reconnaissance teams providing trusted sources of socio-technical challenges. This continues to be a gap in domestic response.

In contrast during Hurricane Sandy, six MERS detachments deployed and were supported by innovation teams (to engage emergent issues), incident management assessment teams (IMAT), which were supported by the new FEMA Disaster Emergency Communications (DEC) division and the Regional Emergency Communication Coordination Working Group (RECCWG).[222] At the same time, local FEMA officials experimented with ICT assessment teams that focused upon coordinating communications efforts using both governmental assets and collaborating with private industry.[223] These efforts were not just in support of operational and logistic concerns but to assist state, local, and the affected population.[224] These communications initiatives are a result of lessons learned from the Hurricane Katrina but are not reflected in changes to NIMS, NECP, or incorporated into the official ICS guides. This is a more robust

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220 Ibid.

221 Ibid., 83.

222 Federal Emergency Management Agency, *Hurricane Sandy FEMA After-Action Report* (Washington, DC: Federal Emergency Management Agency, 2013), https://s3-us-gov-west-1.amazonaws.com/dam-production/uploads/20130726-1923-25045-7442/sandy_fema_aar.pdf, 25; Brian Carney, "Disaster Emergency Communications Division" [PowerPoint] (presented at SWIC Meeting, Washington, DC, June, 2009), National Governor's Association, accessed May 5, 2014, http://www.nga.org/files/live/sites/NGA/files/pdf/0906INTEROPCOORDINATORSCARNEY.PDF;

223 Sean C. Kielty, and John MacLean, "We Know You Can Hear Us: The Model Emergency Communications Response to Super Storm Sandy" (unpublished, Federal Emergency Management Agency 2014).

224 Federal Emergency Management Agency, *Fact Sheet: Mobile Emergency Response Support* (Washington, DC: Federal Emergency Management Agency, 2009), http://www.fs.fed.us/r8/allhazardresponse/All_Hazard_Concept_of_Operations/documents/MERSFactsheet.pdf; Sean C. Kielty, interview with author, September 8, 2014.

approach and demonstrates greater emphasis on communication and the pursuit of restoration as a primary mission objective as opposed to a support mission. The key concept is that there must be plans in place before the impact.

1. Hastily Formed Network Group—Katrina

The Naval Postgraduate School's (NPS) Hastily Formed Network (HFN) team received a request from the Department of Defense (DOD) to provide critical communications services. As the deployment unfolded the HFN team demonstrated the capability to rapidly create wireless connectivity and Internet access in austere conditions. They were initially given a mission to report to Stennis Space Station Mississippi, as part of the Joint Task Force Katrina (JTF Katrina) to restore satellite communication to the Naval Oceanography Center (NAVO), a tenant command on the base. On September 3, 2005, the NPS team was reassigned to the Hancock County Mississippi Emergency Operations Center (EOC). The new mission was to reconnect these regions and to provide satellite-Internet connectivity for local hospital, local government, first responders, and the general public. The NPS-led team, with notable support from the Office of the Assistant Secretary of Defense/Networks and Information Integration (OASD-NII) and private industry (Cisco, Redline, and Mercury Data Systems), "created the first and only official publicly accessible set of broadband wireless hotspot clouds in an area that virtually suffered 100% disruption of all communications capabilities."[225]

> Within 5 hours of NPS's equipment reaching the first site that the EOC requested help with (Hancock County Memorial Hospital) the NPS/Vendor team had satellite broadband Internet, email, VoIP, and web access available for myriad agencies that had set up for emergency operations in the hospital parking lot (including FEMA, Federal Protective Service, Florida Disaster Medical Assistance Teams (DMAT), National Guard Emergency Medical Unit, National Guard Security Unit, Disaster

[225] Brian Steckler, Bryan L. Bradford, and Steve Urrea, *After Action Report and Lessons Learned from the Naval Postgraduate School's Response to Hurricane Katrina* (Monterey, CA: Naval Postgraduate School, 2006), 4.

> Mortuary Team (DMORT), regional ambulance service providers, and the hospital staff.[226]

The NPS team worked from the Hancock Medical Center and expanded the network outwards linking centers of response together (see Figure 6).

The networks and the communications capabilities are the beginning of pockets of local order (PoLO).[227] PoLO is a concept to explain how systems and processes organize in time and space to perform some function.[228] The social organization had been extremely disrupted and a communication system provides the substance and processes for self-organization. The ability to use technology to communicate creates virtual PoLO, affecting emergent and convergent interaction, coordination and organization. The increased flow of information will create challenges for interpretation, processing and dissemination management.[229] The Internet connectivity is a key, and the ability to link to it provides access to a host of tools and capabilities that are far more robust then satellite telephones. Besides basic services (e.g., email, file sharing, voice over IP, chat rooms, video conferencing, crisis response management software), the Internet connection allows for processing and data management to be handled off site, far from the impacted zones. The potential power here lies in organizing and management private industry and the volunteer and technical community (V&TC). Sahana Software Foundation was founded in 2004 in response to the Indian Ocean earthquake and tsunami. This was an early effort of volunteer humanitarian technical volunteerism. The potential to utilize these services were just not available in the U.S. in 2005 as social media was just beginning to coalesce; a trusted network of reliable V&TC had not been formed. The power of these systems and organization, combined with linkages with private industry and with the convergent forces via functioning data network, is the potential that a HFN unleashes. The ability to use up to date geographical information, access to expert systems and databases, and connection to massive processing power is

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[226] Steckler, Bradford, and Urrea, *After Action Report and Lessons Learned*, 5.

[227] Törnqvist, Sigholm, and Nadjm-Tehrani, "Hastily Formed Networks for Disaster Response."

[228] Ibid., 3.

[229] Ibid.

the goal of a technologically modern communication system. The small NPS team was able to demonstrate that this was achievable.

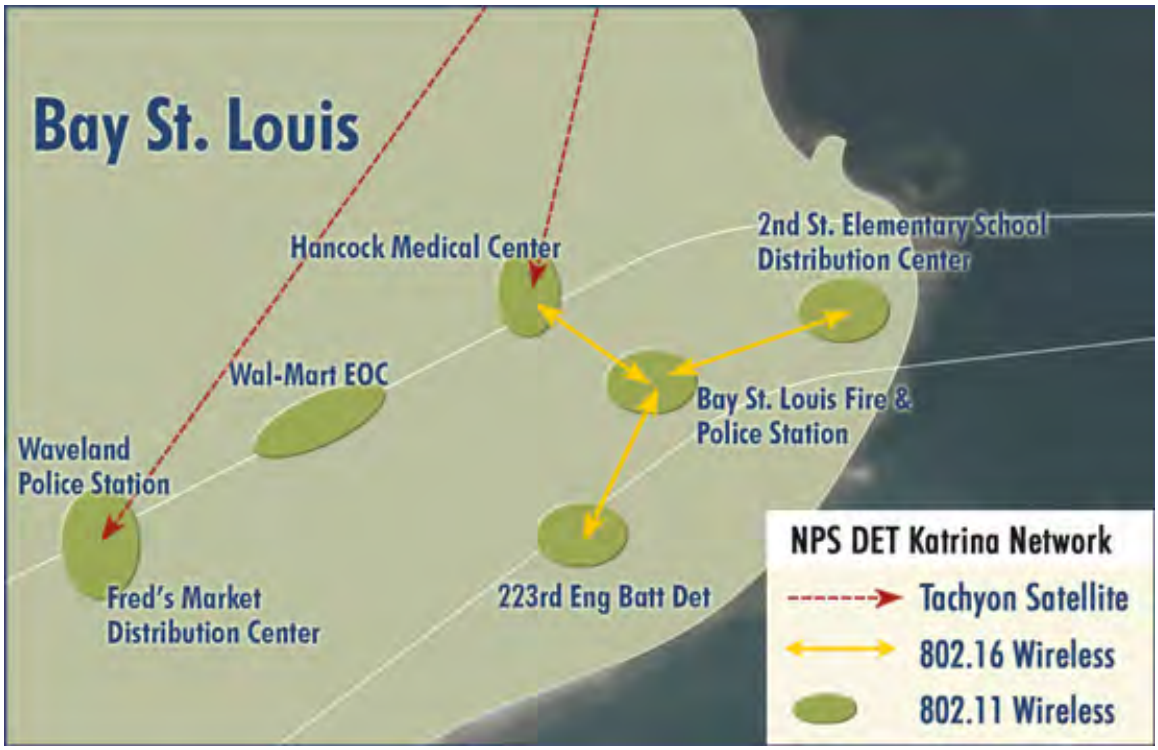

Figure 6. HFN Katrina Network Node Locations, September 20, 2005[230]

E. CONCLUSION

The *Federal Response to Hurricane Katrina: Lessons Learned* report released February of 2006 clearly attributes many of the failures to lack of communication affecting collaboration, command and control, cooperation with local and state response, and logistical and operational management.[231] The report recommends numerous improvements and the creation of a comprehensive, national emergency communications strategy. The *National Emergency Communications Plan* (NECP) that was released in 2008 by DHS formulated goals for improving national emergency communications and a

[230] "HFN Katrina Network Node Locations," September 20, 2005, accessed August 20, 2014, http://faculty.nps.edu/dl/HFN/images/network_fig8.jpg

[231] White House, *The Federal Response to Hurricane Katrina*.

timeline for accomplishing those goals.[232] However, those goals are primarily focused on interoperability radios.[233] In those six years, the information and technology world has moved on exponentially (according to Moore's law[234] this is approximately three lifetimes in technology). In October 2012, Hurricane Sandy devastated the northeastern United States and the FEMA Hurricane Sandy after action report names communication and coordination as significant problems in their response.[235] Though communication was still a problem, the response was approached in a more vigorous manner.

In the 2011 paper entitled "Resilience, Entropy, and Efficiency in Crisis Management: The January 12, 2010, Haiti Earthquake," it states that resilience and efficiency are "largely driven by interactions among organizations participating in disaster operations, their exchange of timely, valid information, and their capacity for learning and adaptation, as well as gaps in cognition and action."[236] The majority of the studies focus upon the effects of communications voids on convergent forces. Decision making and situational awareness are crippled, and the response devolves into disorganization and loss of coordination and productive involvement. Stabilizing the social system as well as attending to environmental concerns is the real objective.

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[232] U.S. Department of Homeland Security, *National Emergency Communications Plan*.

[233] The NECP was updated on November 11, 2014 and assessment has not been included in this study.

[234] Gordon E. Moore's (1965) observed that computing power doubles every two years. This observation represents an exponential growth rate of computing power. Gordon E. Moore, "Cramming More Components onto Integrated Circuits *Electronics* 38, no. 8. (1965): 114–117.

[235] Federal Emergency Management Agency, *Hurricane Sandy FEMA After-Action Report* (Washington, DC: Federal Emergency Management Agency, 2013,) https://s3-us-gov-west-1.amazonaws.com/dam-production/uploads/20130726-1923-25045-7442/sandy_fema_aar.pdf

[236] Louise K. Comfort, Michael D. Siciliano, and Ava Okada, "Resilience, Entropy, and Efficiency in Crisis Management: The January 12, 2010, Haiti Earthquake," *Risk, Hazards & Crisis in Public Policy* 2, no. 3 (2011): Article 1.

V. HAITI CASE STUDY

A. INTRODUCTION

On January 2010, a magnitude 7.0 earthquake rocked Haiti with catastrophic consequences. The small impoverished nation was severely affected: over 100,000 dead, massive destruction and damage to buildings (residential, business and governmental) and failure of fragile infrastructure. This sudden onset disaster resulted in a massive global humanitarian aid/disaster response (HA/DR) effort. The destruction of Haiti's infrastructure (and the communication infrastructure in particular) led to a chaotic environment even the most basic assessments could not be trusted. The World Food Programme (WFP) identified 700 organizations that responded, further straining the coordination efforts.[237] The international response community was unable to overcome the chaotic environment, and its communication systems and resources were soon overwhelmed by the massive needs and requests. The international disaster response was characterized as confused, uncoordinated, ill-informed, and lacking a commonly agreed upon leadership structure. Without a functioning communication system, the disaster response community was unable to develop a common operating picture (COP) to prioritize and organize efficient relief.

The United Nations has had many experiences in disaster response worldwide. The after action reports of disasters like the earthquake in Haiti have brought about significant reorganization of information, communication, and technology (ICT). There is a revolution in worldwide network connectivity. The new technical environments pose new challenges and potentials. Though connectivity is a real problem, responders are being overwhelmed by the massive increase in information flows that are a consequence of the rapid increase in methods to electronically communicate.

The ubiquity of cellular telephone ownership in even the poorest countries, the enormous amounts of data from new streams, and the unreasonable expectations of

[237] Steve Scheinert, and Ralitsa Konstantinova, "Attempting a Knowledge Commons in the Field: the Response to the January 12th, 2010 Haitian Earthquake" (working paper no. 1104, University of Pittsburgh, Center for Disaster Management, November, 2011).

immediacy in a wired world are all overwhelming a process that is essentially limited by the abilities and capacity of the human component. The disaster response workers are inundated with requests for assistance (directly from the affected communities via cellular phones).

The problem is the current methods rely on a workflow that is ancient. Humans must read the report, verify, and distill the important data and then efficiently distribute it. Modern ICT provides enhanced functionality, and it is a source of information overload. The increase in data has not translated into a corresponding increase in human information processing capacity. Connectivity unleashes the potential benefits of distributed computational power, crowdsourcing, data modeling, and multitudes of globally connected volunteers. A massive volume of data from multiple inputs overwhelms responders' ability to process.[238]

The UN experiences in Haiti and the assessment of the information management issues serve as excellent models for domestic initiatives directed at domestic crisis response. Failures of ITC support in Haiti in the first three weeks had far-ranging negative effects throughout both the response and recovery phases.[239] The data from the network analysis points to a response network that was fragmented, organizations that were isolated, information sharing that was inhibited, and the emergent forces were not engaged.

International humanitarian response often demonstrates problems in communication that are more severe than those experienced domestically. In this situation, there are far more agencies from many countries, from diverse cultural backgrounds, speaking many languages, with objectives or political goals that can be incongruent. The challenges of this communications environment are staggering.

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[238] Harvard Humanitarian Initiative, *Disaster Relief 2.0*, 10–15.

[239] Louise K. Comfort et al., "Transition from Response to Recovery: The January 12th, 2010 Haiti Earthquake," *Earthquake Spectra* 27, no. 1 (2011): 411–430.

B. THE CHALLENGES TO ITC IN HUMANITARIAN AID AND DISASTER RESPONSE

The UN HA/DR response to Haiti encountered a catastrophe. Conditions included severely damaged infrastructure, local government in disarray, and an inability to access common data and information that would assist in prioritizing primary humanitarian tasks. The staff and locations housing essential information like maps identifying roads, locations of hospitals, demographics, locations and types of development programs that were underway, were all part of the disaster.[240] Haiti had one working airport, a severely damaged port, harsh environmental conditions, over 100,000 dead or dying, and hundreds of thousands without access to basic needs (i.e., food, water, shelter). This was the situation the international community faced. Its response proved to be one of the biggest humanitarian aid operations in history. Those tasked with facilitating communications had to first reestablish basic connectivity. As connectivity improved, issues with management of information led to sluggish coordination, an inability to collaborate, and the creation of information gaps that hampered damage assessment and response planning.

The UN identified four major causes that contributed to an overloaded crisis communications system that was unable to fill the communication gaps to improve response efficiency (see Figure 7):

1. The UN cluster system that was designed to organize the response created unforeseen obstacles to information sharing.
2. The rapidly growing volunteer and technical communities (V&TC) were able to form some useful partnerships, but they came at a cost.
3. The widespread ability of the affected population to communicate directly via mobile/wireless technology added a new data flow.
4. The advances in modern communication technology created unrealistic expectations.

[240] Harvard Humanitarian Initiative, *Disaster Relief 2.0*, 16.

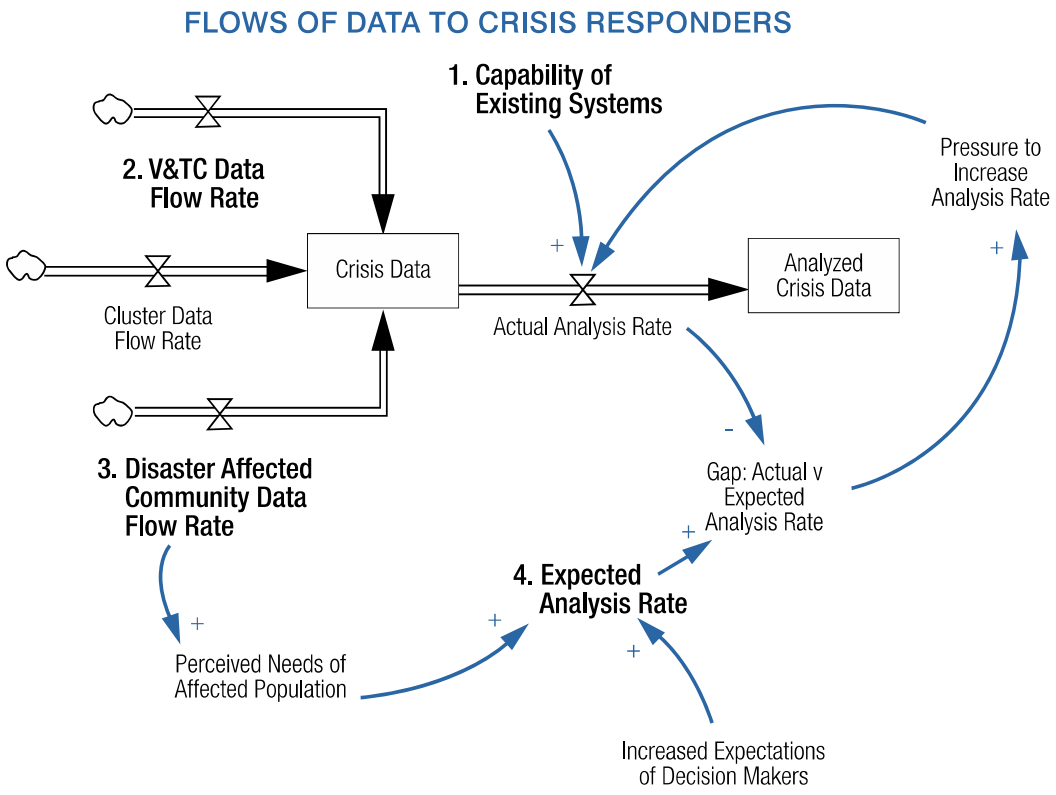

Figure 7. Crisis Response Data Flow Diagram[241]

C. EXISTING SYSTEM

The international humanitarian response, in cooperation with the host country, required the development of a coherent and realistic COP. Field managers consistently reported that they were constantly behind delivering information that was expected. The response efforts were unable to effectively engage local efforts. In addition, communities were isolated and the fragile Haitian social order had disintegrated. International efforts suffered from decision making based upon inaccurate or incomplete information, and local communities were completely isolated and in chaos.

New technologies allow for greater quantities and faster delivery of data, but it does not alter the human capacity to translate data to knowledge—a phenomenon Peter

[241] Ibid., 19.

Denning describes as info-glut.[242] Denning explained that an adverse result of info-glut is that workers become detached and uninvolved and lose the ability to focus.[243]

This situation added to the stress of working in a disaster area that required unbelievable physical effort. Three types of issues commonly emerged from post disaster interviews:

- "Structural issues: Aspects of the information management design used by the UN Inter-Agency Standing Committee (IASC)-led cluster system that restricted information flows within and between clusters.
- Lack of resources: Overreliance on underfunded and understaffed information management units.
- Delays: Delays in information flows due to translation, collation, and analysis."[244]

The cluster system is designed to promote coordination between organizations based on functional needs and substantive areas of response. Ideally, each organization and cluster would provide ICT support and assist communication efforts across various clusters. The lead agency for each cluster would be responsible for ensuring that information management is coordinated and effective between clusters. However, Haiti revealed that ICT resources were insufficient and unable to respond in a timely manner.

In practice, clusters worked to achieve their own goals and had little resources to devote to overall coordination effort. Their efforts were characterized as slow and unproductive. Additionally, events changed faster than weekly meeting could accommodate. Furthermore, information systems became fragmented, data was siloed, and difficult to aggregate. Consequently, organizations were unable to form a COP, and they were unable to adapt, thereby contributing to numerous failures in the response efforts.[245] Although tools and technology have advanced rapidly, the human workflow process and actual human rate of analysis creates a bottleneck.

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[242] Peter J. Denning. "The Profession of IT, Infoglut," *Communications of the ACM* 49, no. 7 (2006): 15–19.

[243] Ibid.

[244] Harvard Humanitarian Initiative, *Disaster Relief 2.0*, 20.

[245] Scheinert, and Konstantinova, "Attempting a Knowledge Commons in the Field," 13.

The UN analysis linked inadequate resources to failures in inter-cluster and intra-cluster coordination. Adequate resources, which increased the reliance on human intervention, did not match the dramatic increase in data flows and connectivity options. In a harsh environment of disaster response, the field-staff, who were attempting to address the overwhelming needs of the affected population, also faced greater burden and expectation of information management.

Information during crisis response is time sensitive, and delays alter understanding of perceived needs, resources, or goals. Some delays (e.g., from translation) were expected. For example, the delay created by translating documents and messages between English, French, and Creole. The UN was unable to keep up with the translation needs. Although this would have been an excellent opportunity to outsource, this time consuming task to trusted V&TC. The UN response community had no formal manner to enlist V&TC, translations were of uneven quality and generally disregarded (unless it came from a trusted source).

Although using V&TC mapping, messaging and text tracking and positive connectivity collaboration with Télécoms Sans Frontières, proved successful. There were no formalized procedures to vet, interact or evaluate the information flow or any pre-operation relationships with new and often ad-hoc V&TC. The groups that were successful were those that had established relationships with responders prior to the disaster.[246]

> The international response suffered from inability to restore a communications system. The system that emerged was not an effective network and did little to engage the affected communities. The ICT assets were inadequate for a catastrophic response and were directed to support the desperate needs of the clusters leads. The experienced UN crisis response planners had made significant plans to address communications gaps but the strategy suffered from inadequate ICT resources, unforeseen data flow increases and a failure to address communications as a system.

[246] Harvard Humanitarian Initiative, *Disaster Relief 2.0*, 26.

D. HASTILY FORMED NETWORK GROUP—HAITI

The NPS HFN Center was contacted to deploy to Haiti as part of the Joint Forces Maritime Component Command (JFMCC) and later the Joint Task Force Haiti (JTF Haiti). The NPS team had previously worked with the JFMCC during deployments to Katrina (in 2005) and the tsunami in southeast Asia (in 2004). From the U.S. Navy hospital ship (USNS) *Comfort* (T-AH-20) the team (seven members) "was directed to support and provide advice (and communications capability as we brought a fair amount of SATCOM/MESHED WIFI/WIMAX and alternate power equipment with us)."[247] From the beginning, the NPS team found communication as both the "biggest obstacle and the biggest enabler."[248] Larry Wentz, a senior research fellow at the National Defense University, observed, "most responders agree ICT is important in helping save lives and to help coordinate relief efforts but few treat it as an essential service beyond meeting their own needs."[249] The NPS team began work from the USNS *Comfort* and gradually expanded the scope of its mission and the diameter of its HFN network.

The team began work to address the urgent need for communication in an extremely chaotic and hazardous environment. For the first 10–15 days, there was an inability to acquire solid information, develop any sort of situational awareness, or share information due to massive degradation of the communication infrastructure.[250] As the NPS-team began to expand its network using satellite based Internet services, it found that web based information portals, social networks, and collaboration tools were popularly used.[251] The team found that Skype (a messaging software that allows voice-over-IP, instant messaging, and video conferencing) was an excellent collaboration tool. Brian Steckler was able to start an ad-hoc and informal chat group of global subject

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[247] Brian Steckler, *Haiti Earthquake after Action Report and Lessons Learned (AAR/LL)*, (Monterey, CA: Naval Postgraduate School, 2010).

[248] Steckler, *Haiti Earthquake after Action Report and Lessons Learned*, 4.

[249] Larry Wentz, *Haiti Information and Communications Observations Trip Report for Visit 18 February to 1 March 2010* (Washington, DC: National Defense University, 2010), 8.

[250] Steckler, *Haiti Earthquake after Action Report and Lessons Learned*.

[251] Ibid., 7.

matter experts (SME); this ability strengthened social links and increased trusted relationships.

The NPS team pushed out and augmented network and connectivity from the U.S. Coast Guard port facilities (see Figure 8). During the deployment, the team traveled on assessment reconnaissance to ascertain the status of communication.[252] One of these trips led to successfully assisting the Haitian Community Hospital of Petionville. The hospital was basically overwhelmed and unable to communicate urgent needs for either UN or U.S. military assistance. Wentz found that an overall communications plan to connect the healthcare sector was missing and efforts appeared ad-hoc.[253] The team supported the hospitals communication efforts. These efforts were without direct order but reflected the distributed command structure within a chaotic environment.

In the post event analysis, the NPS HFN team found problems integrating into a complex international response. The technical problems ranged from a lack of interoperability, poor-information sharing, severe challenges to collaboration, and an acute need for comprehensive process that addresses communication holistically. The NPS team led efforts to untangle the conflict caused by organizations not prepared to manage frequencies. Developing frequency plans was an unforeseen problem, and the consequences were that the communication hardware was constantly interfering with each other.[254] Consistently, the most valuable commodity was bandwidth; there never seemed to be enough. The chaotic communications environment reflected a misunderstanding of the essential nature of communication to successful response.

[252] Ibid. 17.

[253] Wentz, *Haiti Information and Communications Observations*, 27.

[254] Ibid.

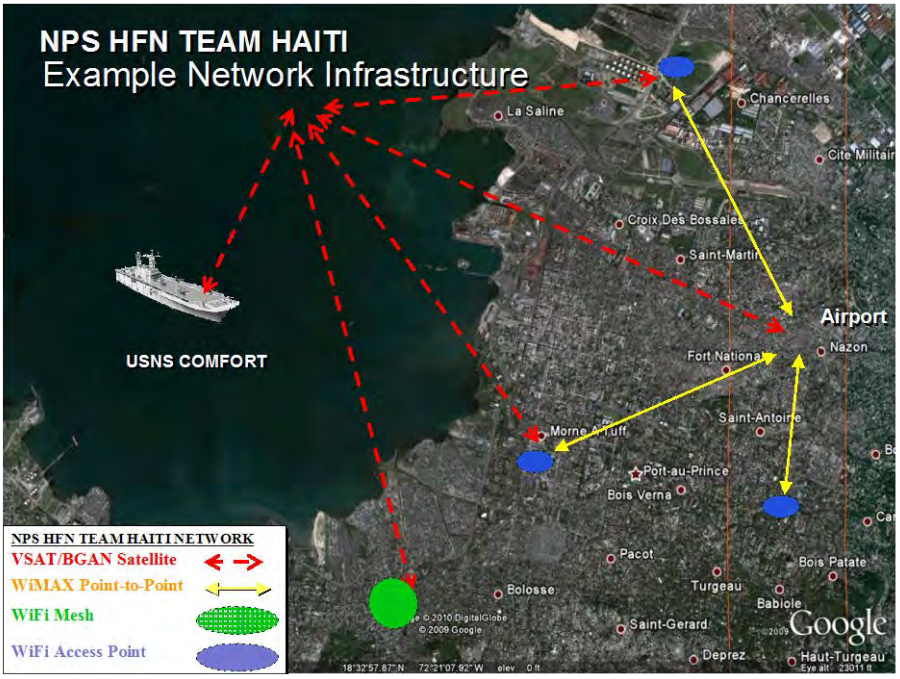

Figure 8. HFN—Haitian Network Map[255]

[255] Brian Steckler, "Hastily Formed Networks (HFN)" (presented at Naval Postgraduate School, October 2011).

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VI. RESPONSE NETWORK ANALYSIS

A. NETWORK ANALYSIS

During Hurricane Katrina and the earthquake in Haiti, the networks that evolved and emerged had significant structural problems. The common criticism of the crisis response was an inability to create a functional communication system in a timely manner. The result was a response that has been characterized as unable develop SA or COP (that had severe effects on decision making), an inability to engage the affected population, and plagued by poor coordination. The lack of an overall communications strategy led to a network evolution that was ad-hoc without meaningful ICT intervention by the convergent forces.

Social network analysis (SNA) is a method of analysis utilizing network theory on social networks, illustrating the relationships that link nodes (organizations) to each other. Using SNA, complex network maps are created and statistical tools provide an understanding of network behavior, relationships, and patterns. These measures reveal topographical and organizational patterns such as connectivity, centrality, influence, and efficiency. A catastrophic event is primarily a disruption to the social network and society's response to that disruption. Examining the dynamics of social networking of response organizations provides an understanding of the evolutionary process of a communications system. The SNA data examined shows networks that are disconnected and unable to engage responding organizations or effectively link the affected population.

1. Katrina Response Network Data

The analysis of Hurricane Katrina networks relies on three studies and the corresponding datasets. The data measured network formation during the initial response period. The authors of the studies kindly provided access to the datasets, or the data was publically available. The studies were:

- Carter Butts, Ryan Acton, and Christopher Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response" (data publicly available)[256]
- Louise K. Comfort at the Universty of Pittsburgh, Center for Disaster Management
- Naim Kapucu at the Department of Public Administration, University of Central Florida

2. Katrina Response Network

The three studies each use different data acquisition, coding, and modeling methods. The different methodologies led to a significant difference in the numbers of organizations involved, definition of node or link, and the length of time studied. The data collection and analysis approaches are detailed in Appendix A. However, the studies are in agreement that the crisis network that emerges had significant topological problems that inhibited the flow of information. The network was unable to provide an effective communications system in a timely manner. A communication system is "most effective when information management is linked to information exchange and social communication techniques and processes."[257] The Katrina networks did not build the links and establish the relationships to create a functional network and were unable to share information efficiently.

Using the data three studies that tracked network dynamics using social network analysis of the emergent Katrina network the following patterns develop:

- Networks were highly fragmented and loosely coupled.
    - The fragmentation continued at a high rate for an extended period.
    - The majority of participating organizations operated in isolation and were unable to share information.

[256] Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response."

[257] Susana A. Barrantes, Martha Rodriguez, and Ricardo Pérez, eds., *Information Management and Communication in Emergencies and Disasters: Manual for Disaster Response Teams* (Washington, DC: Pan American Health Organization, 2009), http://www.paho.org/disasters/index.php?option=com_content&view=article&id=644&Itemid=879&lang=en

- A giant central component (sub-network) emerged.
  - This component evolved following the model of Barabási and Reka model for scale-free network.[258]
  - The central component was overwhelming populated with convergent organizations.
  - These organizations had access to stable communications systems.
  - The giant component follows natural network evolution. Network growth is not managed.
- Lack of emergent engagement
  - The majority of reported participating organizations are categorized as local (municipal, city, county/parish, and state).
  - The sub-networks that are identified reflect dominance by convergent organizations.

B. KATRINA ORGANIZATIONS

The three studies use different methodologies that track participation of organizations or groups over time. Table 2 illustrates the number of organizations and the jurisdictions represented. The data acquisition methodologies are detailed in Appendix A.

[258] Barabási, and Réka "Emergence of Scaling in Random Networks."

Table 2. Hurricane Katrina Participating Agencies

Organizations Breakdown Percentage	Butts, Acton, & Marcum[259] 8/23-9/5	Comfort & Haase[260] 8/27-9/19	Kapucu, Arslan, & Collins[261] 8/25-9/25
International	8.3	3.7	-------
Federal	17.1	31.4	9
Regional	2.9	6.2	-------
Interstate	1.3	-------	-------
State	38	17	27
Sub-Regional	------	6.2	-------
County	10	13.6	23
Local	15.7	21.9	11
City	5.7	-------	-------
Non-Profit	-------	-------	14
Private	-------	-------	16
Total Percentage	100[262]	100	100
Numbers of Organizations	1577	535	580

The data shows a majority of organizations involved to be in from the local to the state level (see Table 3).

[259] Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response."

[260] Comfort and Haase, "Communication, Coherence, and Collective Action.

[261] Naim Kapucu, Tolga Arslan, and Matthew L. Collins, "Examining Intergovernmental and Interorganizational Response to Catastrophic Disasters: Toward a Network-Centered Approach," *Administration & Society* 42, no. 2 (2010): 222–247.

[262] Addition of 1.1 percent of data missing jurisdictional equals 100 percent. Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response," 8.

Table 3. Hurricane Katrina Participating Agencies—Local Agencies

Local Response	Percentage
Kapucu, Arslan, and Collins[263]	61.0
Comfort and Haase[264]	58.0
Butts, Acton, and Marcum[265]	69.4

C. NETWORK DISCONNECTION

At its most basic level, a crisis response network needs to be able to pass information between the participating organizations. The emerging network was heavily fragmented and loosely linked during the period studied. It displays high isolates counts (organizations without links), high levels of fragmentation (few connected sub-networks), and low levels of network centralization.[266]

Viewing a static network map of the Katrina response networks is deceptive. The aggregate static map (that tracks all interactive links throughout the studies) shows a large, well-connected network (Figure 9). It is essential to view the maps dynamically. The dynamic network maps in Appendix A clarifies the disconnected nature of the network over time.

[263] Kapucu, Arslan, and Collins, "Examining Intergovernmental and Interorganizational."

[264] Comfort and Haase, "Communication, Coherence, and Collective Action."

[265] Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response."

[266] Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response;" Comfort and Haase, "Communication, Coherence, and Collective Action;" Kapucu, Arslan, and Collins, "Examining Intergovernmental and Interorganizational Response;" Scheinert, and Konstantinova, "Attempting a Knowledge Commons in the Field."

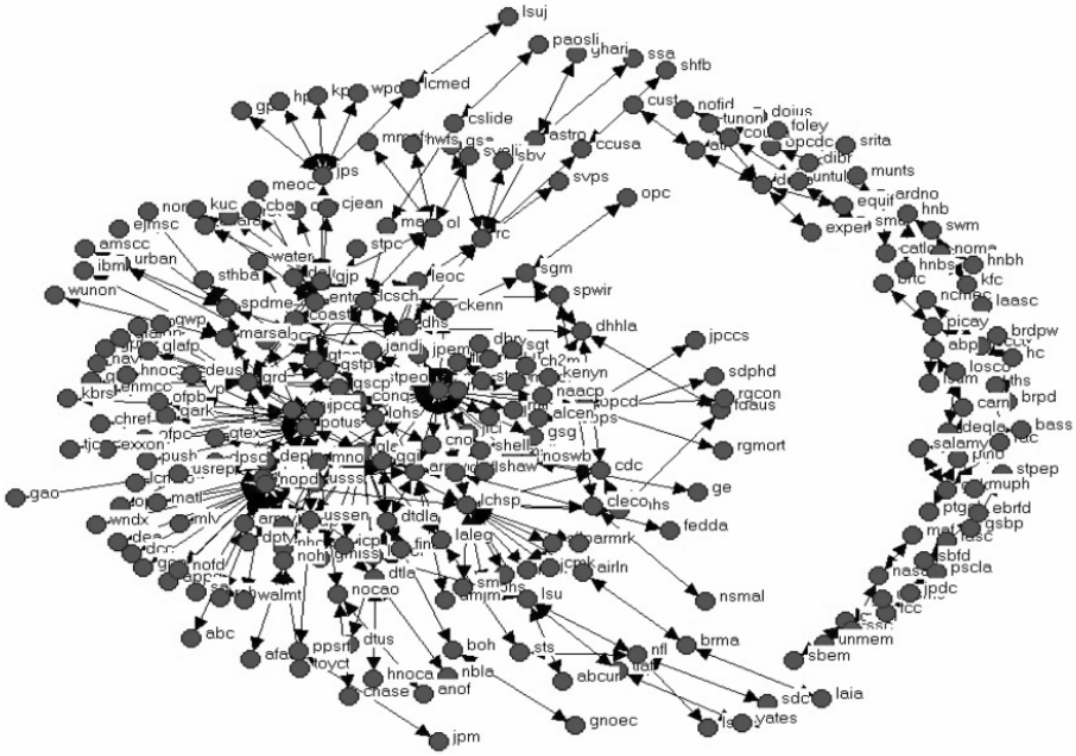

Figure 9. Diagram of Network Interaction Hurricane Katrina August 27 to September 19, 2005[267]

D. NETWORK FRAGMENTATION

Using the Butts, Acton, and Marcum data,[268] a network fragmentation chart illustrates the percentage of network fragmentation over time (see Figure 10). This chart demonstrates that the majority of organizations were isolated during the response to Hurricane Katrina and that this fragmentation remained high. The network expands rapidly in the study, but the percentage "generally fluctuates around the mean of 67.34%."[269] The result is that information sharing was extremely restricted and inhibited. Figure 18 illustrates the steady state of non-isolate components (sub-networks) through the study. The maximum size of the largest component reached 219 organizations out of

[267] See Appendix A for legend of organization included in network analysis. Comfort and Haase, "Communication, Coherence, and Collective Action."

[268] Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response."

[269] Ibid.

775 identified organizations on September 4, 2005.[270] As the response efforts expanded (the increase in number of participating organizations), the new organizations participating were unable to establish links. Those organizations that were linked had limited access to new sources of information. One large sub-network emerges surrounded by smaller disconnected sub-networks and isolated organizations (see Figure 11).

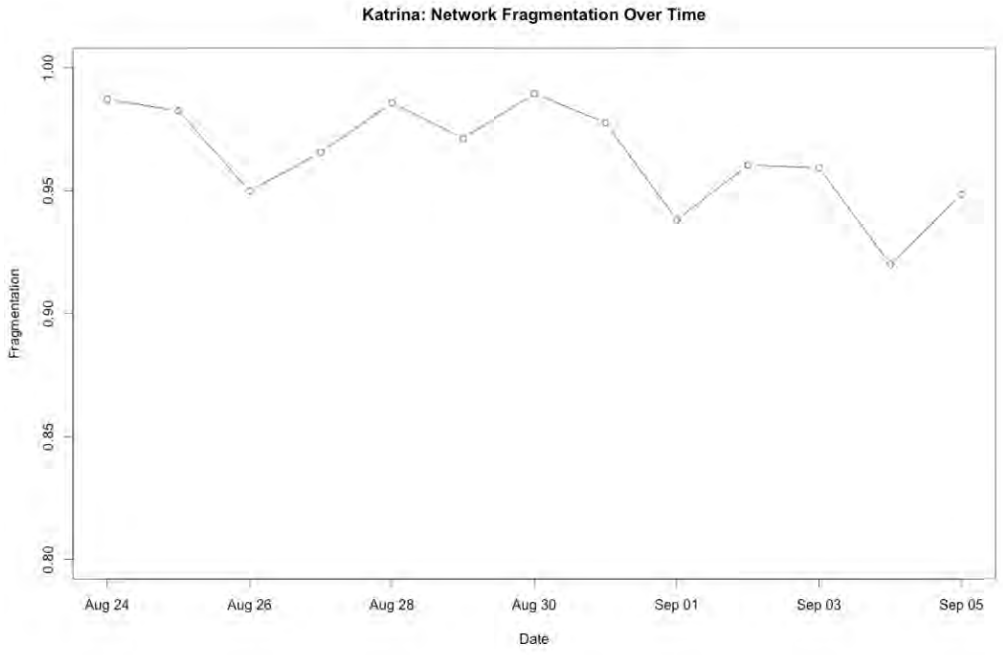

Figure 10. Hurricane Katrina: Network Fragmentation August 24 to September 5, 2005 (2012 Dataset)[271]

[270] Ibid.

[271] Ibid.

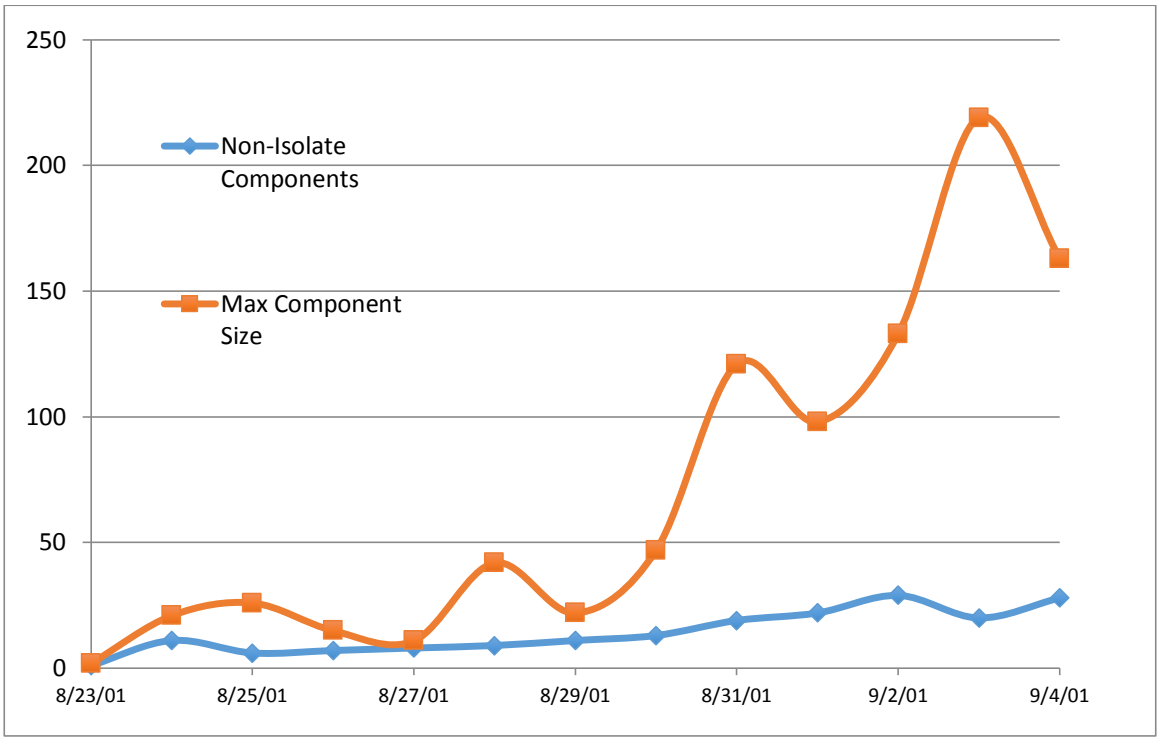

Figure 11. Hurricane Katrina: Non-Isolate Components August 24 to September 5, 2005 (2012 Dataset)[272]

E. CENTRALITY—DEGREE, CLOSENESS, BETWEENNESS

Centrality is regarded as one of the most important and commonly used conceptual tools for exploring actor roles in social networks. The number of links to an actor is degree centrality. By definition, the "central actors must be the most active in the sense that they have the most ties to other actors in the network or graph."[273] Centrality is a conceptual tool that examines the roles and characteristics of actors (organizations) within a network. The degree centrality measures the number of links of an actor in comparison to the total number of links possible in a network. Organizations with the most links have the higher degree of centrality. This measure is often a rough measure of an organization's influence within the network. Table 4 presents mean degree centrality

[272] Ibid.

[273] Stanley Wasserman, and Katherine Faust, *Social Network Analysis: Methods and Applications* (New York: Cambridge University Press, 1994).

and network centralization. From the Butts, Acton, and Marcum data,[274] average degree centrality can be seen to remain low for the network over the span of the study (see Figure 12). The data from all three studies find a network that on average has few links per node and that network centralization values point to a loosely coupled network.[275]

Table 4. Hurricane Katrina Mean Degree Centrality and Network Centralization

Data Set	Degree	Network Centralization
Kapucu, Arslan, and Collins[276]	1.821	14.22
Comfort and Haase[277]	2.422	15.96
Butts, Acton, and Marcum	1.087	2.79

[274] Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response."

[275] Note: Full descriptive statistics is in Appendix A. for each study. Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response;" Comfort and Haase, "Communication, Coherence, and Collective Action;" Kapucu, Arslan, and Collins, "Examining Intergovernmental and Interorganizational Response."

[276] Kapucu, Arslan, and Collins, "Examining Intergovernmental and Interorganizational Response."

[277] Comfort and Haase, "Communication, Coherence, and Collective Action."

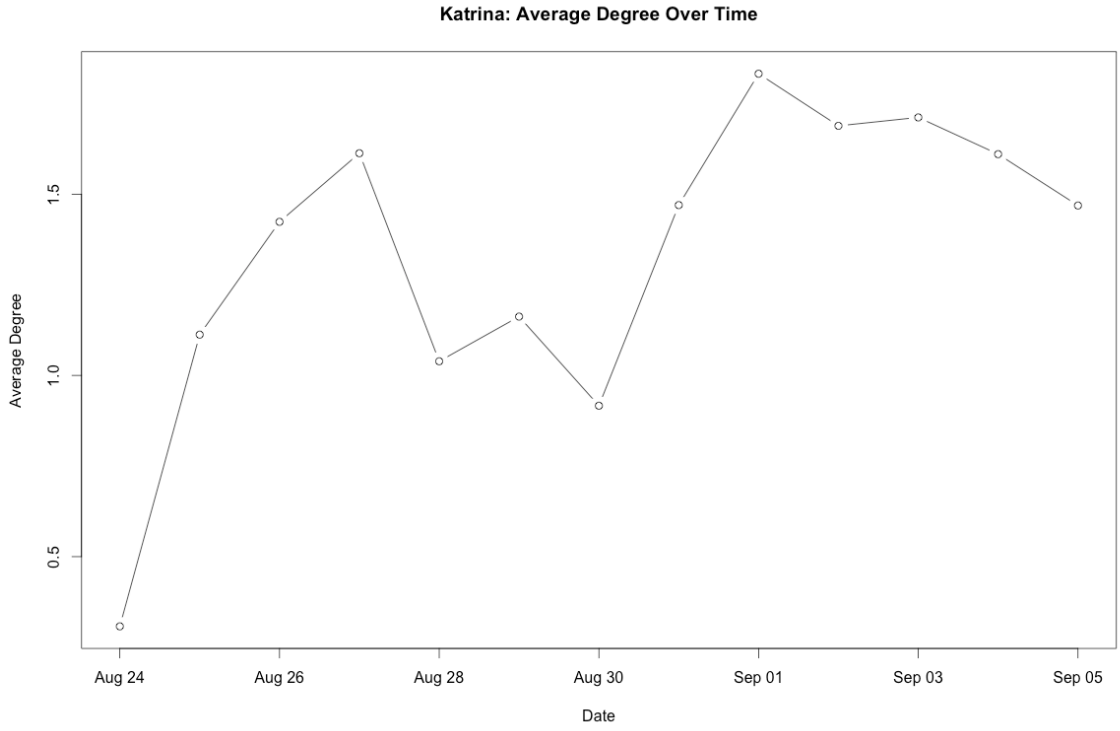

Figure 12. Hurricane Katrina Average Degree Centrality August 24 to September 5, 2005 (2012 Dataset)[278]

In analyzing the degree centrality, the difference of the data collection methods displays some interesting variances. Comfort and Haase identified eight organizations with the highest degree centrality (FEMA, National Guard, president of the United States, governor of Louisiana, New Orleans Police Department, local hospitals, government of Jefferson Parish, and Mayor of New Orleans).[279] The majority of these agencies are within the affected region. The Kapucu, Arslan, and Collins data[280] reflects greater degree centrality of convergent forces but still the majority of organizations with a high degree centrality are from the affected area (see Table 5). The data is at odds with the Butts, Acton, and Marcum study[281] in Table 6; nine of the top 10 organizations are outside the affected regions (convergent forces). The explanation lies in the data

[278] Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response."

[279] Comfort and Haase, "Communication, Coherence, and Collective Action."

[280] Kapucu, Arslan, and Collins, "Examining Intergovernmental and Interorganizational Response."

[281] Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response."

collection methods. The data from Comfort and Haase study[282] was acquired from content analysis of news reported from the *Times-Picayune* (the major newspaper of New Orleans). This data set was constructed from participating organizations operating within the affected area. The Kapucu, Arslan, and Collins (2010) data[283] was acquired through content analysis of a wider variety of sources (for a full description see Appendix A). In 2012, the Butts, Acton, and Marcum study[284] identified 1577 operating organizations through analysis of 63 source organizations. This study represents a far larger data collection effort (for a full description see Appendix A). This study found that "organizations having considerable prior experience with disasters and/or with advanced disaster preparedness measures and infrastructure in place tend to dominate the list of high-degree actors."[285]

Table 5. Organizations' Highest Degree Centrality[286]

Organizations	Degree
Florida State Emergency Response team	84
Federal Emergency Management Agency (FEMA)	67
Mississippi Emergency Management Agency (MEMA)	51
Florida	48
American Red Cross (ARC)	41
Emergency Management Assistance Compact (EMAC)	37
Alabama	33
Alabama Emergency Management Agency (ALEMA)	26
Mississippi	23
Louisiana	21

[282] Comfort and Haase, "Communication, Coherence, and Collective Action."

[283] Kapucu, Arslan, and Collins, "Examining Intergovernmental and Interorganizational Response."

[284] Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response."

[285] Ibid., 19.

[286] Kapucu, Arslan, and Collins, "Examining Intergovernmental and Interorganizational Response," 235.

Table 6. Ten Highest Central Degree Organizations[287]

Organizations	Degree
Colorado Division of Emergency Management (DEM)	45
American Red Cross	41
Texas State Operations Center	36
U.S. Federal Emergency Management Agency (FEMA)	30
Emergency Management Assistance Compact (EMAC)	27
Georgia State Operations Center	27
Dry Tortugas/Everglades National Park	26
Florida SERT, Emergency Support Service Branch	25
Alabama EMA, Emergency Operations Center, ESF 9	23
Missouri Emergency Management Agency (EMA)	23

F. CLOSENESS AND BETWEENNESS

Closeness and betweenness centrality describes an actor's position within a network structure. These metrics are not as useful on an uncoupled network with high fragmentation. The Butts, Acton, and Marcum data[288] displays a giant component (sub-network). Using closeness and betweenness that giant component can be better understood as a functional response network. The metrics describe a network that conforms to network theories on network evolution.

Closeness centrality measures that can identify actors that are best suited to pass information in a network.[289] The closeness of an actor is a measure of its path length to other actors compared to all other actors.[290] An actor with a low closeness score reflects shorter paths to other actors, increasing the likelihood of information sharing. This

[287] Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response," 12.

[288] Ibid.

[289] Wasserman, and Katherine Faust, *Social Network Analysis*, 49.

[290] Linton C. Freeman, "Centrality in Social Networks. Conceptual Clarification," *Social Networks* 1, no. 3 (1979): 215–239.

calculation measures network efficiency, a network with actors that are far from each other have difficulty sharing information.[291] A problem with closeness is that a highly fragmented network will not provide closeness centrality measures that are useful. Isolated actors do not have a path to other actors. The isolated actor data needs to be eliminated for closeness centrality measurements. The resulting components are examined and the centrality metrics (closeness, betweenness) can be used to determine the sub-network behavior and structure.

All three studies identify a large component of connected actors within the fragmented network. A comparison of the closeness measures for the three studies are in Appendix A. The studies agree that the high-level fragmentation made closeness centrality irrelevant for the entire network. Both the Comfort and Hasse study and the Kapucu, Arslan, and Collins study show a "very high mean" measure for "farness," farness means that actors do not have short path lengths to share information. The network is unconnected so no measure of network centralization can be calculated.[292] This lack of connectivity displayed results in difficulty of crisis response organizations in coordinating activities.

The Butts, Acton, and Marcum study examines the level of closeness within the giant component that emerges.[293] The giant component is the largest sub-network within the whole network. This emerging component represents a cluster of organizations that forms ties and can achieve a level of information sharing and collaboration that is otherwise missing. The giant component evolves following general network formation characteristic that resemble a scale-free network.[294]

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[291] Steve P. Borgatti, "Centrality and Network Flow," *Social Networks* 27, no. 1 (2005): 55–71.

[292] Comfort and Haase, "Communication, Coherence, and Collective Action," 10;

[293] Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response;" Kapucu, Arslan, and Collins, "Examining Intergovernmental and Interorganizational Response," 234.

[294] Barabási, and Réka, "Emergence of Scaling in Random Networks;" Barabási, *Linked: The New Science of Networks*.

G. GIANT COMPONENT

In Katrina, the emerging network displayed the mechanisms that govern network evolution: growth, preferential attachment, and attachment related to fitness.[295] Using the Butts, Acton, and Marcum data,[296] the aggregate network follows a power law distribution (see Figure 13). Hubs evolution and popularity (greatest number of links) exhibits the characteristics of a scale-free network. A large central component (sub-network) emerged that reflected linkage based on a physical location, access to ICT, existing relationships, task-related factors, and organizational lines.[297] In addition, actors that had high levels of centrality and acted as bridges (actors with highest measure of closeness), and they were headquartered and conducting business outside the affected areas with access to undamaged ICT resources.[298] The giant component was almost exclusively made up of convergent forces. The data suggests that the convergent forces were unable to engage the affected communities or develop ties to emergent groups. The Katrina response forces had significant ICT assets and trained personnel but did not have a plan or strategy to intervene aggressively and to restore a communication network rapidly.

[295] Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response;" Barabási, *Linked: The New Science of Networks*.

[296] Butts, Acton, and Marcum, "Interorganizational Collaboration in the Hurricane Katrina Response."

[297] Ibid.

[298] Ibid., 22.

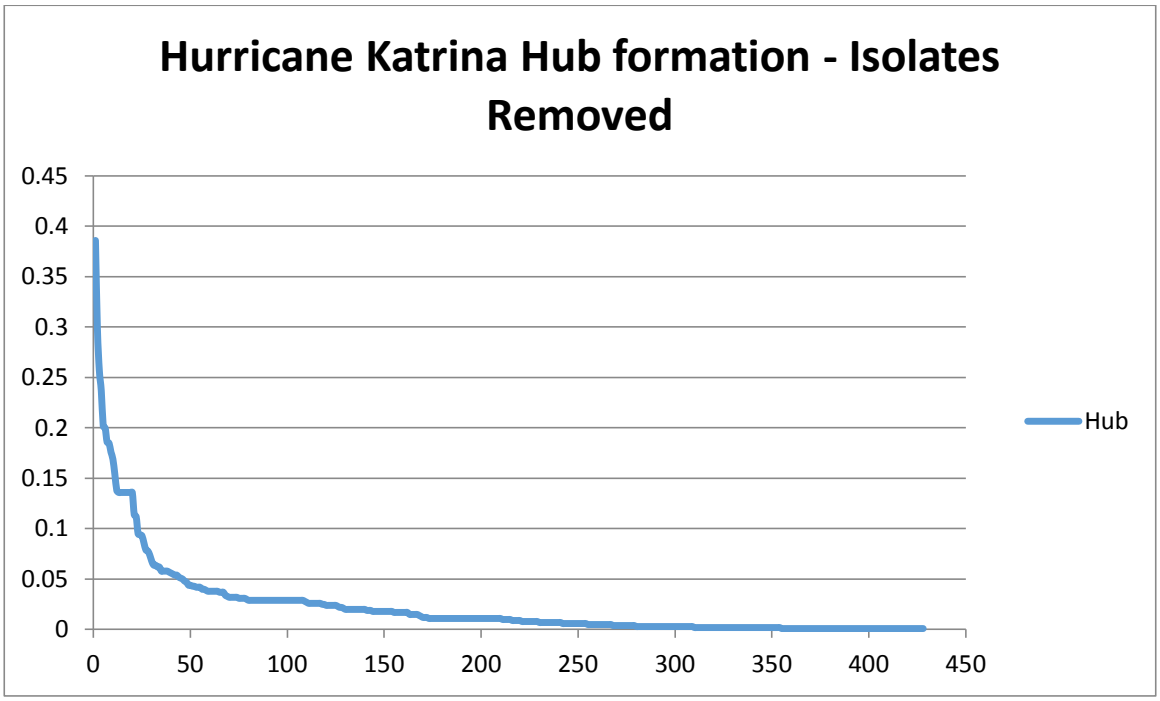

Figure 13. Hurricane Katrina Hub Formation[299]

The actors who successfully linked into the response network were those in a greatly favored position. The missing component of this response was a strategy that sought to gain control of the disrupted socio-technical communication system. The data shows that the network was fragmented, and actors isolated for an extended period. That the level of fragmentation remained high even as the response grew rapidly. The greatest number of response actors could be defined as local. The Butts, Acton, and Marcum data[300] illustrates that the actors converging from outside the affected regions had a far greater chance of establishing links and share information. These actors made up a sub-network (giant component) that behaved according to network theory. The majority of actors unable to establish links were the affected communities and emergent groups that are such essential to restoring stability to the social system.

[299] Ibid.

[300] Ibid.

H. HAITI NETWORK ANALYSIS

The data from the Haiti response illustrates the lack of engagement of emergent groups and the affected communities. The data from the University of Pittsburgh studies tracked organizational interaction over a three-week period from the onset of the event. The networks created in the studies have a high level of fragmentation and a high degree of disconnectedness.[301] The response network that evolved suffered high number of isolated organizations, and a network that structurally had severe difficulty sharing information. Additionally, the resultant network suffered from poor coordination and a lack of efficiency. A large, well-connected sub-network (giant component) formed similar to the Katrina studies. The data reflects a disconnection between organizational planning and the reality of crisis response. The UN OCHA occupies an organizational and management position as the leader and coordinator of the 13 functional clusters. Data from the studies demonstrate that centrality and hub formation conformed to fitness attributes and preferential attachment. The inner sub-network grew as organizations converged on the affected region, but it was unable to link rapidly to organizations that were not established partners in the region or part of the international response communities. The cluster approach depends heavily upon the voluntary coordination and self-organization of the affect nation. The studies note a complete lack of linkage with local organizations.[302]

The analysis of the response networks from the earthquake in Haiti relies on the data from studies from the University of Pittsburgh, Center for Disaster Management (CDM). The CDM studies use two primary data acquisition methods and are differentiated as groups A and B. The studies in the A group uses three types of data over a three-week period following the event:

- "Content analysis of daily news reports—tracking organizational participation.
- Documentary reports of organizational action from governmental and professional sources.

[301] Comfort, and Okada, "Emergent Leadership in Extreme Events," 63.

[302] Ibid., 67.

- On-site semi-structured interviews with responsible managers."[303]

The content analysis relies heavily upon *Caribbean News Online* (CANA) and is not the definitive "analysis of network organization."[304] The data reflects regional views and reporting content. Data gleaned from a content analysis of the *New York Times* presents distinctly different results.[305]

The Group B studies utilize the Group A data combined with an analysis of the situation reports published by 11 different organizations from ReliefWeb.[306] A more detailed description of the data collection and analysis approaches is in Appendix B.

Group A

1. Comfort, Louise K., Siciliano, Michael D., and Okada, Aya. "Resilience, Entropy, and Efficiency in Crisis Management: The January 12, 2010, Haiti Earthquake." 2011.
2. Comfort, Louise K., Siciliano, Michael D., and Okada, Aya. "Evolving Systems in Crisis Management: The January 12, 2010, Haiti Earthquake." 2012.
3. Comfort, Louise K. and Okada, Aya. "Emergent Leadership in Extreme Events: A Knowledge Commons for Sustainable Communities." 2013.

Group B

1. Scheinert, Steve and Konstantinova, Ralitsa. "Attempting a Knowledge Commons in the Field: the Response to the January 12th, 2010 Haitian Earthquake." 2011.
2. Siciliano, Michael "The Use of Exponential Random Graph Models to Investigate the Micro-Level Processes of Inter-Organizational Network Formation." 2011.

[303] Louise K. Comfort, Michael D. Siciliano, and Aya Okada, "Evolving Systems in Crisis: The January 12, 2010 Haiti Earthquake," in *Mega-crises: Understanding the Prospects, Nature, Characteristics, and the Effects of Cataclysmic Events*, ed. Ira Helsloot et al. (77–91) (Springfield, IL: Charles C Thomas, Publisher, 2012), 80.

[304] CANA—Major Caribbean regional print and broadcast media outlet. Comfort, Siciliano, and Okada, "Evolving Systems in Crisis."

[305] Comfort, Siciliano, and Okada, "Evolving Systems in Crisis."

[306] ReliefWeb: largest portal for humanitarian information sharing. The portal is administered by UN OCHA.

I. HAITI ORGANIZATIONS

Scheniert and Konstantinova document nearly 700 participating organizations using data from the Sahana Foundation.[307] Louise Comfort, Michael Siciliano, and Aya Okada tracked organizational interactions and participation utilizing a content search of the *Caribbean News Online* (CANA).[308] The response network found was primarily composed of international organizations.[309] The data also reflects an almost total lack of linkage to affected communities (see Table 7). The emergent efforts are difficult to track the missing data, and the official reports demonstrate an inability to link the affected communities in a timely manner.

Table 7. Distributions of Organizations Participating in the Haiti Response[310]

	Public		Private		Nonprofit		Total	
	N	%	N	%	N	%	N	%
International	97	56.7	17	9.9	13	7.6	127	74.5
Regional	22	12.9	4	0.2	6	3.5	32	18.8
National	10	5.9	0	0.0	1	0.1	11	6.5
Local	1	0.1	0	0.0	0	0.0	1	0.2
Total	130	76.0	21	12.3	20	11.7	171	100.0

J. NETWORK DISCONNECTED

Similar to the Hurricane Katrina, static network map the aggregated links of the entire study is deceptive (see Figures 14 and 15). The dynamic network maps are included in Appendix B, and they provide a clearer picture of network behavior and evolution over the time studied. The dynamic maps show a network that has a high level of fragmentation over an extended period for convergent actors and a lack of emergent connection.

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307 Scheinert, and Konstantinova, "Attempting a Knowledge Commons in the Field."

308 Comfort, Siciliano, and Okada, "Evolving Systems in Crisis."

309 Comfort, Siciliano, and Okada, "Resilience, Entropy, and Efficiency in Crisis Management," 11.

310 Ibid., 9.

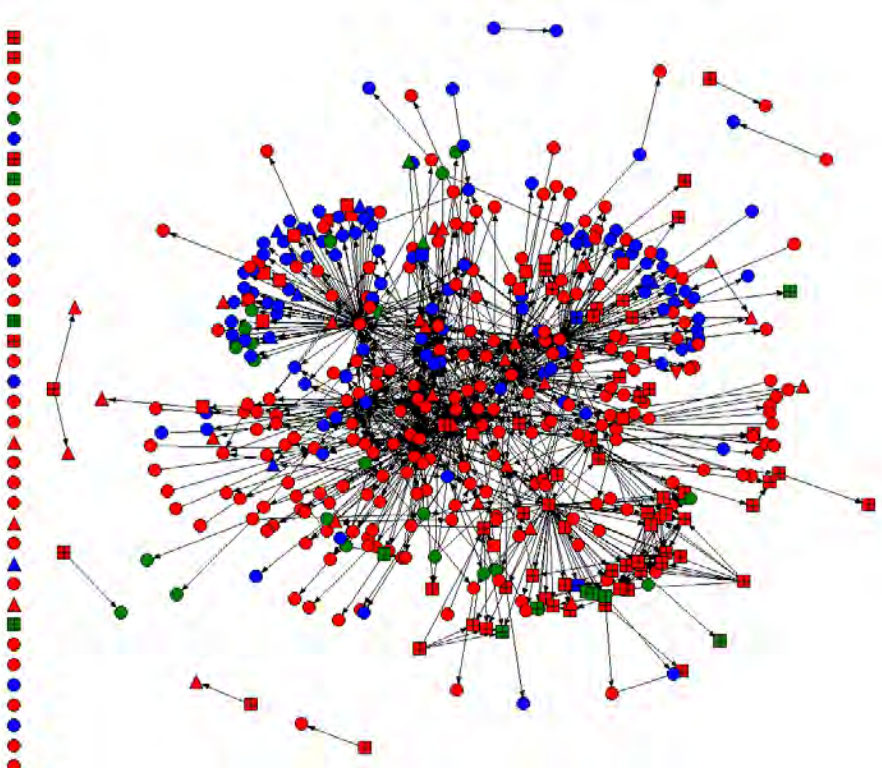

Figure 14. Earthquake in Haiti—Static Network[311]

Organizational Source of Funding	
Source	Color
Public	
Private	
Non-Profit	

Organizational Jurisdiction	
Jurisdiction	Shape
Local	Square
Subdepartmental	Down Triangle
National	Up Triangle
Regional	Box
International	Circle

Figure 15. UCINet Network Map Key for Node Colors and Shapes[312]

311 Scheinert, and Konstantinova, "Attempting a Knowledge Commons in the Field."

312 Ibid.

K. NETWORK FRAGMENTATION

Scheniert and Konstantinova clearly demonstrate the high level of fragmentation within the response network (see Figure 14).[313] The dips in fragmentation are a result of connections made at the weekly cluster meetings at the logistical base. These once a week meetings provided means of coordination and sharing information.[314] The CDM reconnaissance trips to Haiti confirmed this pattern. Researchers witnessed difficulties sharing information, ad-hoc use of ICT, information velocity determined by paper processes, and human cognitive capacity.[315] The result was a response network that had a large number of isolated organizations and high levels of fragmentation (see Figure 16).

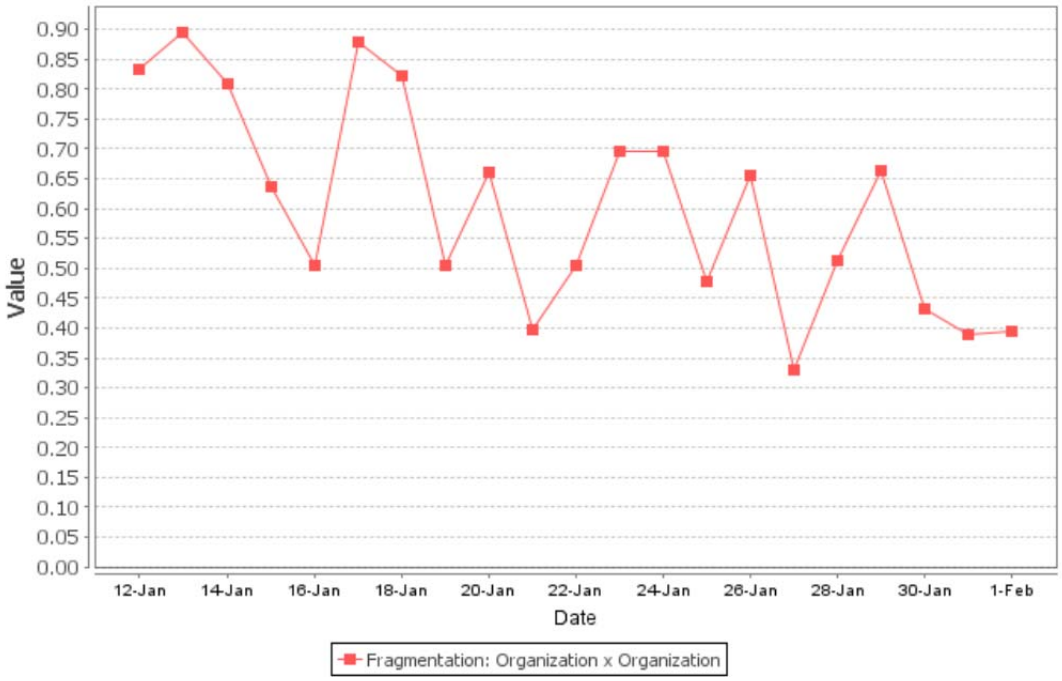

Figure 16. Network Fragmentation, Dynamic Network[316]

[313] Ibid.

[314] Ibid., 11–12.

[315] Harvard Humanitarian Initiative, *Disaster Relief 2.0*; Scheinert, and Konstantinova, "Attempting a Knowledge Commons in the Field," 11–12.

[316] Scheinert, and Konstantinova, "Attempting a Knowledge Commons in the Field," 9.

L. CENTRALITY

The analysis of degree centrality and network centralization by Louise Comfort, Michael Siciliano, and Aya Okada is presented in Table 8. The degree centralization is 20.33 and indicates a loosely connected network. The normalized mean number of links for actors is 2.56. This measure confirms limited connectivity between actors. The Scheinert and Konstantinova found key organizations emerged as highly linked hubs and often served as bridges (see Figure 17).[317] These hubs served the informational need of a smaller sub-network (giant component) but due to the high number of isolates, the overall network had severe barriers to information flow.[318] The Haiti response network shows similarities to the Katrina network. The high isolate counts and fragmentation combined with highly clustered sub-network. Comfort, Siciliano, and Okada found the high clustering ratio to the distance ratio represented a small-world network within the larger system (Table 9).[319] A small-world network is a natural occurring feature of large real-world networks. This feature results in a number of large clusters with small linkage paths.[320] This network structure can be a source of efficiency for those actors with links to the clusters. Conversely, the high fragmentation rate means the large network is unable to cooperate effectively and coordinate. This reflects a communications system that was not managed at a strategic or tactical level. Modern ICT provides inexpensive access to advanced network monitoring and management tools. A communication strategy in crisis response understands that it is essential to recreate the links (that have been disrupted) and that the resulting network is a dynamic system. This system needs help to grow and vigilant oversight of its evolutionary process.

317 Ibid.

318 Comfort, Siciliano, and Okada, "Evolving Systems in Crisis," 87.

319 Ibid.

320 Watts, and Strogatz, "Collective Dynamics of 'Small-World' Networks," 440.

Table 8. Network Centralization Descriptive Statistics[321]

Network Descriptives	Degree	Normalized Degree	Share
Mean	2.839	2.558	0.009
Std Dev	3.902	3.515	0.012
Sum	318.000	286.486	1.000
Variance	15.224	12.356	0.000
Sum of Squares	2608.000	2116.711	0.026
Minimum	1.000	0.901	0.003
Maximum	25.000	22.523	0.079
Overall Network Centralization	**20.33%**		

Table 9. Small World Network within the Haiti Response System, January 12–February 3, 2010[322]

Network Measure	
Clustering Coefficient (CANA)	0.393
Average Distance (CANA)	3.251
Average Clustering (Random Graph)	0.026
Average Distance (Random Graph)	4.435
Clustering Ratio	13.236
Distance Ratio	0.729
Small World Ratio	18.168

[321] Comfort, Siciliano, and Okada, "Resilience, Entropy, and Efficiency in Crisis Management," 11.

[322] Comfort, Siciliano, and Okada, "Evolving Systems in Crisis," 87.

Figure 17. Most Central Organizations, Static Network[323]

Under the cluster system's official organization, the lead organizations are UNOCHA and the Logistics Cluster. The data show that the most central organizations in the response were the WASH Cluster (UNWASH) and UNICEF, closely followed by the World Food Program (WFP). UNOCHA only reaches a position where it is tied with several other organizations that are in the top ten of only 15 percent of the centrality measures.[324] The expectation from the cluster system design would be the UN OCHA would be the most central organization. The data shows that organizations linked directly to the cluster leads (UNWASH, UNICEF, and UNWASH). UNOCHA was not central to managing connections, serving as an information conduit or serving as a leader inter-organization coordination.[325] This example serves to demonstrate that networks evolve following principles and forces that do not necessary follow design expectations.

M. NATIONAL RESPONSE AND COMMUNICATIONS

The *National Response Framework* (NRF), *Catastrophic Incident Annex* (CIA)[326] acknowledges that there is a difference between the disasters and catastrophic events. However, there is not a corresponding acknowledgment that a new communications

[323] Scheinert, and Konstantinova, "Attempting a Knowledge Commons in the Field," 7.

[324] Ibid., 8.

[325] Ibid.

[326] Federal Emergency Management Agency, *Catastrophic Incident Annex*.

approach is needed. A review of the official response documentation displays a lack of a comprehensive communications strategy. The 2013 NRF acknowledges the importance of communication, emphasizes community engagement, but there is a gap in the crisis response management doctrines that describe any new organizational initiatives.[327]

The *National Incident Management System* (NIMS)[328] has not been updated since 2008 as the technical landscape has progressed in capacity, power, and complexity. At the same time, Incident Command System (ICS) is turning 40 without a significant overhaul. In 2010, the FEMA Disaster Emergency Communications (DEC) attempted to alter ICS, adding DEC and MERS as a part of the Operations Section. Though tactical communications and an aggressive plan to assess and respond to communications is a good step, this is a continued splintering of the communications and information effort.

- 2010 National Incident Management System *Incident Command System Emergency Responder Field Operations Guide*—Communication is a Unit in Logistics (see Figure 18)
- 2009 *Interim ICS Handbook* (expires January 1, 2010)—Has DEC and MERS in the Operations organizational chart. This is inconsistent with living ICS documentation (see Figure 19).[329]

[327] U.S. Department of Homeland Security, *National Response Framework*.

[328] U.S. Department of Homeland Security, *National Incident Management System*.

[329] Federal Emergency Management Agency, *Incident Management Handbook* (FEMA B-761) [interim] (Washington, DC: Federal Emergency Management Agency, 2009), http://www.aphis.usda.gov/emergency_response/downloads/hazard/Incident%20Management%20Handbook6-09.pdf Manual expires 2010.

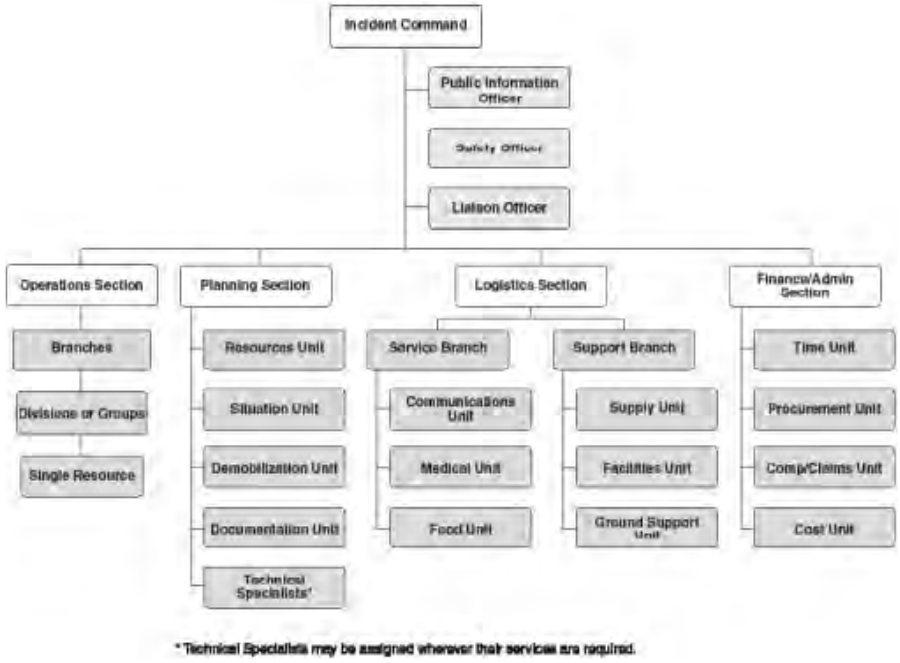

Figure 18. FEMA *Incident Management Handbook*—Organizational Chart[330]

[330] Federal Emergency Management Agency, *National Incident Management System Incident Command System Emergency Responder Field Operations Guide* (Washington, DC: Federal Emergency Management Agency, 2010), http://montanadma.org/sites/default/files/FEMA-2009-0014-0002-1_0.pdf, 2–10.

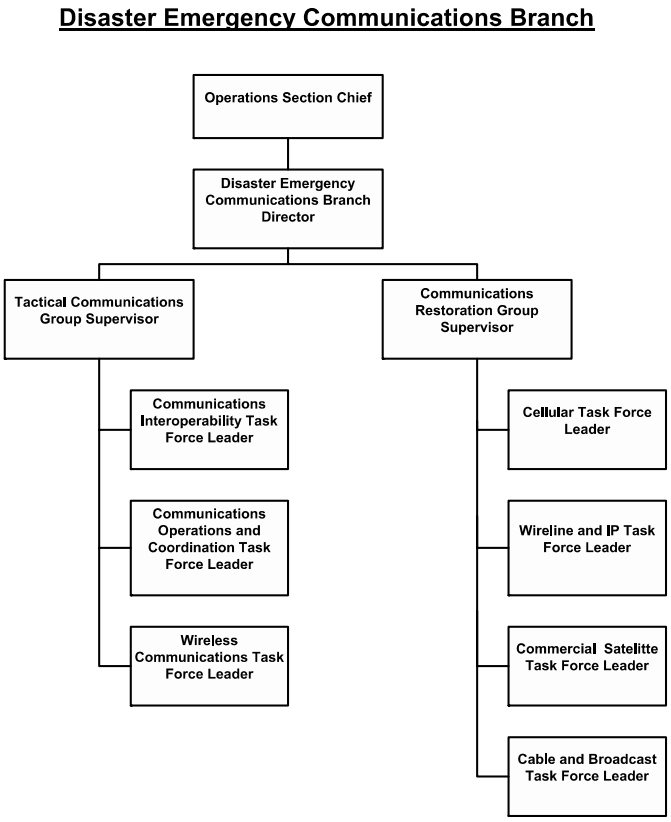

Figure 19. FEMA *Interim ICS Handbook* (expires January 1, 2010)—Disaster Emergency Communications Branch[331]

The changes made from the 2009 *ICS Handbook* and the FEMA *Interim ICS Handbook* reflect a substantial change of the position of crisis communications. The interim handbook creates a branch for communications within operations.[332] Communications is still a unit within the Logistics section. The changes do not create a communications leadership role. DEC's role is subordinate to the operations section chief, and the communications unit remains in logistics. A review of current live documents and the official ICS course-work offered by FEMA does not reflect that the interim *ICS Handbook* changes are official organizational policy.

[331] Ibid.

[332] Ibid.

The Emergency Support Function #2 (ESF) part of the NRF serves to identify the organizations that have overall responsibility for communications.[333] The documents have gone through considerable review since 2004 (see Appendix E.).

- ESF #2 (2004) Communication the Primary Agency: DHS
- ESF #2 (2008) Communication the Coordinating Agency: Department of Homeland Security/National Protection and Programs/Cybersecurity and Communications/National Communications System;
- ESF #2 (2008) represents split command.
    - Primary agencies: DHS/National Protection and Programs/Cybersecurity and Communications/National Communications System Federal Emergency Management Agency
- ESF #2 (2013) updates the 2008 but continues the split command. Communication the Coordinating Agency: Department of Homeland Security/National Protection and Programs/Cybersecurity and Communications;[334]
    - Primary agencies: DHS/National Protection and Programs/Cybersecurity Communications/National Communications System and Federal Emergency Management Agency
- The whole community concept is introduced that describes vague policies to gain situational awareness from each responding level at the same time passing accurate and relevant information downward. ESF #2 also intends to "accomplishes this by providing assistance to stabilize and reestablish critical infrastructure quickly and efficiently, coordinating requests for additional support, identifying and integrating resources and capabilities, and coordinating information flow."[335] (See Appendix E.)
- However, the NRF 2013 still has the National Communication System as the primary agency even though it was disbanded in 2012.

ESF #5 part of the NRF serves to identify the organizations the agencies that have overall responsibility for information management. Initially, this ESF was responsible for emergency management. The 2013 revision represents a greater emphasis on information management as the primary focus. The documents have gone through considerable review since 2004 (see Appendix E.).

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[333] Federal Emergency Management Agency, *Emergency Support Function #2.*

[334] Ibid.

[335] Ibid.

- ESF #5 (2004) Emergency Management the Primary Agency: FEMA[336]
- ESF #5 (2008) Emergency Management the Primary Agency: FEMA[337]
- ESF #5 (2013) Information and Planning the Primary Agency: FEMA[338]
    - This update recognizes the importance of information management as opposed to emergency management. Information management and communications are defined by separate organizational structures. The natural fit is for communications and information to be closely tied. Information and communication do not necessarily need to be conjoined. However, a comprehensive set of communications and information management strategies are naturally complementary. Combining the two functions may be unwieldy but the common synergistic energy, the emphasis on ICT and interconnection of those functions would suggest integration as a preferred answer. This does not address the political barriers that such an organizational alteration entails.
- NIMS (2008) elevated communications without making serious structural changes to ICS or create and overall crisis communications strategy. It has not been updated since 2008.[339]
- *National Emergency Communication Plan* updated in 2014—not reviewed for this study.
- National Level Exercise—2011—dedicated to catastrophic response focused on interoperability and redundant communications. These were tested, but the communications system was assumed stable for the exercise.

The official documentation that describes domestic crisis response lacks an overall communications strategy. The communications and information management resources and personnel are fragmented. Domestic response planners do appreciate the importance of communication and the essential assistance required from emergent groups, but there is little to guide future response to attaining these objectives. The updates to the NRF and ESF #2 and #5 in 2013 name the "whole community" as a crucial

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[336] Federal Emergency Management Agency, *Emergency Support Function #5 Emergency Management*, 2004, http://www.usda.gov/documents/ESF05.pdf

[337] Federal Emergency Management Agency, *Emergency Support Function #5 Emergency Management*, 2008, http://www.fema.gov/pdf/emergency/nrf/nrf-esf-05.pdf

[338] Federal Emergency Management Agency, *Emergency Support Function #5 Emergency Management*, 2013, http://www.fema.gov/media-library-data/20130726-1913-25045-9548/final_esf_5_information_and_planning_20130501.pdf

[339] Department of Homeland Security, *National Incident Management System*.

component of crisis response. There are several programs that appear to engage and assist the organization of emergent forces (notably the FEMA Community Emergency Response Program (CERT)). However, there does not exist a strategy, the ICT resources have not been significantly enhanced, and there has been no significant alteration of ICS.

The National Level Exercise (NLE) 2011 after action report prepared by FEMA identified the first point as communications.[340] FEMA found strengths in satellite communications established between counties, state, and FEMA whole community engagement as well as private sector and NGO engagement. The weaknesses found were resource gaps, whole community engagement (namely lack of a formal mechanism for engagement), and policy and planning.[341] However, the participants did not use communications sections of the scenario.[342] The participants demonstrated an ability to use alternative methods of communication and then assumed communications were stable. As the case studies demonstrate the communication system during catastrophe continued to be unstable for an extended period and the networks that evolved were structurally incapable of efficiently sharing information and integrating the emergent groups with convergent response. The NLE 2011 is six years after Katrina and a year after Haiti but demonstrates that communications are not understood to be a foundational system and a strategic priority.

[340] Federal Emergency Management Agency, *National Level Exercise 2011 (NLE 11) Functional Exercise -Final After Action Report* (Washington, DC: Federal Emergency Management Agency, 2011), https://info.publicintelligence.net/FEMA-NLE2011-AAR.pdf

[341] Federal Emergency Management Agency, *National Level Exercise 2011*, 2–4.

[342] Ibid., 14–15.

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VII. FINDINGS

The case studies found the catastrophic response systems both displayed critical communications failures. This failure by two distinctively different response systems displays a commonality. Both systems lack a comprehensive strategic communications plan. The communications efforts supported response functions (i.e., operations, planning, logistics, administration) and the needs of the organizations involved.

No plans were in place to rapidly restore communications in the affected communities. Additionally, there was no plan to manage network evolution. The network analysis demonstrates that events, organizational position, needs, and ICT capacity drove linkage within the emerging response networks.

A communications system requires a mechanism for linkage. The links define the emergent response network. The network analysis showed that the emerging response networks were structurally unsound. A majority of organizations were isolated, and the isolation rate remained high for the length of the study. Without links, a network is incapable of sharing information, making correct decisions, or effectively coordinating a massive inter-organizational response. The non-isolated sub-networks did behave following network theory principles. The findings indicate that the participants of these networks and their ability to link to other actors followed theories on network evolution (growth, preferential attachment, and fitness attributes). The affected communities were not actively reconnected as part of any official plan, and this inhibited self-organization.

The Haiti response was five years after Katrina and the same problems are experienced. However, the march of technological progress has uncovered new obstacle to effective communication. The increase reliance on ICT and the ubiquitous usage of cell phones have led to an exponential growth of incoming data flows. A modern communications system requires the resources to manage this ever-increasing deluge.

Communication disruption is a continual problem in crisis response, so much so that it has almost become an acceptable environmental factor in the response community. However, the NPS HFN teams have demonstrated that crisis communications systems

within the affected communities can be achieved with minimal personnel and equipment costs.

The communications unit remains buried in the Logistic Section. The ESF #2 has two primary agencies that do not necessarily have the same goal.[343] FEMA is the primary agency for ESF #5, but the information functions are more naturally a synergistic fit for a new overall information and communication technology function. ICS also needs to create a new Communications Section. This section chief would be part of the ICS general staff, have a voice in an overall strategy and have the ability to pursue goals other than support for other sections. This section would be responsible for the implementation of a comprehensive communications strategy.

It is important to realize this thesis is about crisis response, communication, and that it uses data from two historic case studies. There are substantial differences between international and domestic response. The common problems identified in the case studies is the failure implement a comprehensive communications strategy. Two different methods of organization and management with similar underlying defects. The findings focus on an analysis of the framework that governs communications efforts for domestic response.

The changes made post-Katrina reflects the official reorganization and updates of the NRF and ESF from 2008 to 2013. These reveal an understanding of the importance of addressing communication, especially when considering the acceleration of ICT capabilities. However, the resources are not substantially different than those devoted to Katrina (the MERS detachments are relatively the same strength) while continuing to fragment the ICT efforts. There is some criticism of ICS as an organization structure that has problems dealing with catastrophic events. The recommendation of rapid technology assessment teams (RTAT) is a solution that potentially allows flexibility, adaption, and decentralized organization within the overall hierarchical structure. These small units would be deployed in the impacted zones to acquire information on communications capabilities. An important aspect is the teams would operate autonomously; this

[343] Federal Emergency Management Agency, *Emergency Support Function #2.*

organization represents a distributed and flexible command system. During Hurricane Sandy, the FEMA Disaster Emergency Communications (DEC) experimented with rapid assessment teams that were devoted to reconnaissance and specifically addressed communications gaps. These teams were successful in coordinating communications efforts and were a step in the right direction.[344] The use of these teams are not officially part of crisis response doctrine.

[344] Kielty, and MacLean, "We Know You Can Hear Us."

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VIII. RECOMMENDATION

A. COMMUNICATIONS STRATEGY

Crisis response planning requires the adoption of an effective communications strategy. This strategy must (i) address complexity; (ii) identify the role communications serves as a mechanism to control chaos; (iii) foster self-organization; (iv) integrate the social forces that emerge and converge during a catastrophic event; (v) manage network evolution; and the expected deluge of data.

This strategy could achieve these objectives by incorporating:

1. Rapid deployment of ICT teams to assess technical environment and to share trusted information with converging forces.
2. Hastily formed networks teams to connect with forwardly deployed assessment teams and begin networking local areas of organization using advanced ICT then extend those networks.
3. Develop a network following HFN concepts to: utilize advanced ICT solutions to create a network that satisfies social and technical communication needs.
4. Manage the network evolution
5. Manage information

The strategy makes the rapid reestablishment of communications systems a primary objective. Utilizing small technically adept teams similar to those deployed by NPS would be a catalyst for network growth in the affected communities and serve an information bridge to converging organization. The linked communities are in a better position to self-organize. However, there is a need for intensive network and information management. As seen in the Haiti response, the return of connectivity will create a massive influx of data. Lastly, the network itself needs careful management. The control of ICT assets and bandwidth management would be effective management tools. There is a need to develop techniques that effectively track dynamic network evolution. Future research could be directed towards developing tracking and management tools.

B. RAPID TECHNOLOGY AND ASSESSMENT TEAMS

A method of controlling chaos is the introduction of small perturbations. Deploying small technical teams that are focused on aggressive restoration of communication represent small changes (perturbations) that will have nonlinear effects on the chaotic environment. The use of these teams requires careful pre-planning and extensive feedback once committed. This first wave begins the reestablishment of a network working from identified centers of organization and linking adjacent actors (organizing emergent groups).

The goal is active engagement of emergent groups and improving the chances integration of convergent forces. The centers of organization and the dominant convergent agencies will see rapid increase of network linkage as the network grows and follows the forces of preferential attachment and fitness attributes. The emergence of hubs is an alteration of 'orbits' within a chaotic system. The "orbits" or hubs forms the basis of attraction. These basins represent local organization via a communications system that is aimed at restoring local order. A catastrophe over a large region will be broken into many localities with local gravitation to stability.

C. ICS RECOMMENDATIONS

One of the biggest problems for effective domestic response to disasters is the organization model to which federal, state, and local efforts must conform. The mandate explicitly ties all emergency communication plans to the *National Incident Management Plan* (NIMS) and Incident Command System (ICS). The ICS (mandated by Congress in the Homeland Security Act 2002) is a national emergency response system that is used at all large-scale domestic emergency incidents. Domestic disaster response agencies must follow this strictly hierarchical complex systematic tool for command and control. Incident Command System (ICS) is a crisis response organization and management system that has been in use for more than 40 years. This system is often criticized. For instance, Louise K. Comfort states that this hierarchical model has proven to be unable to

deal with the complexity of large-scale disaster.[345] Hurricane Katrina illustrates the communication problems that academic criticism tie to ICS inflexibility. Comfort argues that ICS strength relies on stable operating conditions and it is unable to respond effectively to the chaos of a complex disaster the size of Katrina, complicated by the failure of the communication infrastructure.[346] According to Moynihan, "Crises are defined, in part, by decisional urgency (Rosenthal, t'Hart and Charles 1989, 18), and a little time can make a big difference in response effectiveness (Comfort 1988, 9)."[347] He also comments, "With limited time, the Katrina network largely failed to coordinate itself or improve response until after terrible suffering occurred. Time is an essential ingredient in learning."[348]

ICS organization must acknowledge the importance of communication as a crucial section and should not bury it in the Logistic Section (see Figure 20). Elevating communications as a new section centralize information and communications technology (ICT) efforts, provide access to the ICS general staff, and alters the status within the ICS response matrix. The communications section chief has improved lines of communications with other section chiefs, assume information and communication functions that are currently spread throughout ICS. The Communications Section would also be better able to assemble, train, deploy, and coordinate rapid technology assessment teams (RTAT) applying HFN concepts. Most importantly, the Communications Section would be responsible for the planning and implementation of a comprehensive communications strategy.

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[345] Louise K. Comfort, "Crisis Management in Hindsight: Cognition, Communication, Coordination, and Control," special issue, *Public Administration Review* (December 2007): 188–196.

[346] Ibid., 190.

[347] Moynihan, "What Makes Hierarchical Networks Succeed?,"

[348] Donald P. Moynihan, *From Forest Fires to Hurricane Katrina: Case Studies of Incident Command Systems*, IBM Center for the Business of Government, 2007, http://www.rrt9.org/external/content/document/2763/716399/1/ICS%20from%20forest%20fires%20to%20Katrina%20-%20Moynihan.pdf, 18.

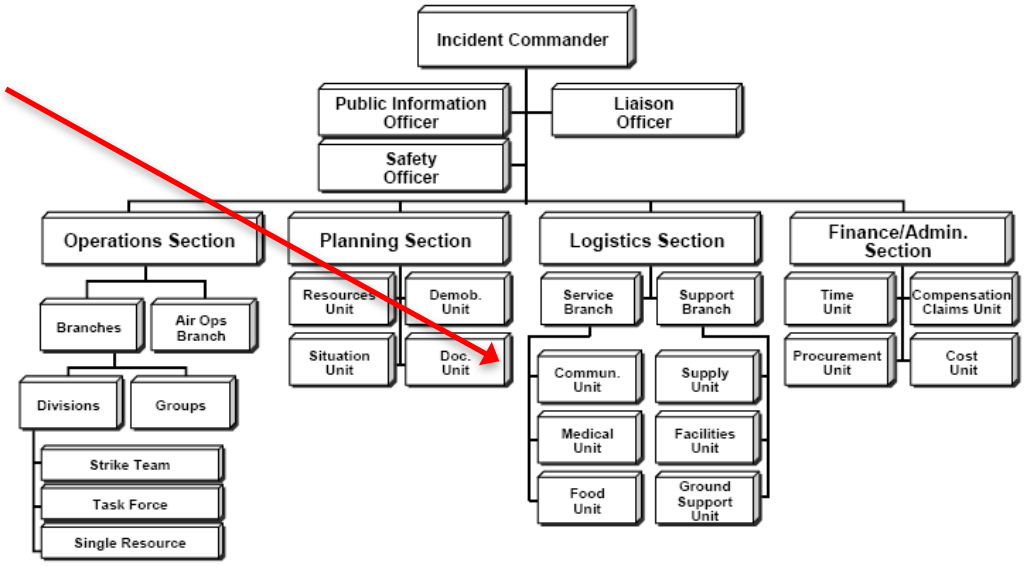

Figure 20. FEMA—ICS Handbook[349]

Since 2005, FEMA has devoted significant effort to improving communication and the implementation of ICT. There has not been a corresponding reorganization with ICS that acknowledges the importance of communication systems or an overall communication strategy. The goal of a functioning communications system is to create an accurate situational awareness and a common operating picture, improve the ability of agencies to cooperate and to establish control to the response. Comfort states, "Control in disaster operations cannot be achieved through hierarchical measures alone."[350] The UN is challenging its policies and organizations in the face of revolutionary changes in ICT; however, FEMA has done little to challenge a system that the entire U.S. response community has been mandated to use. Comfort is one of many academics that call for changes in a "process (that) cannot function effectively on a wide scale under the rigid constraints imposed by the current organizational design and procedural requirements of the National Response Plan and the National Incident Management System."[351]

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[349] Federal Emergency Management Agency, *National Incident Management System*.

[350] Comfort, "Crisis Management in Hindsight," 192.

[351] Ibid.

D. FUTURE RESEARCH

The Hastily Formed Network (HFN) Research Group at NPS offers an excellent model to increase capacity using small academic laboratories. Grants to educational centers for the development of HFN-like centers where research can be performed with an understanding that the school is required to field a team when called upon. These teams would offer ICT surge capacity and offer academic groups the opportunity to improve upon field study.

The HFN Research Group provides field-testing of rapidly deployed emergency information and communication solutions. The group provides an academic research setting that has practically applications in the field. The location in the Naval Postgraduate School has provided the group with important links to the Department of Defense and its humanitarian assistance and disaster response efforts. They have deployed to Katrina, Haiti and most recently to the Philippines during Typhoon Yolanda. This group has an impressive track record, participated in numerous disaster response exercises, and has built a large body of field data. The teams are structured to rapidly deploy, has extensive transportable communication kits, and are expected to be self-supportive. Field researchers need experience in the implementation of advanced information and telecommunication technologies and an ability to work in extreme conditions.

There is an urgent need for these kinds of skills. Funding and grants could be made available to academic institutions that have a desire to perform fieldwork and to test advanced disaster ICT. Tying funding to deployment requirements would create surge capacity. Formation of these groups would require the creation of a variety of guidelines and standards that would clearly define operational and technical parameters. These groups would serve as an adjunct to response communications needs and develop practitioner knowledge and academic research opportunities within crisis response.

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IX. CONCLUSIONS

The purpose of this thesis is to discover what critical functions are needed to limit the destructive, chaotic phase in catastrophic response. Communications are the key and integral function. A primary objective of the thesis is the aggressive restoration and vigorous support of a communications system. Crisis responders must develop a comprehensive communications strategy.

The central theme to this thesis is that a catastrophe is primarily an extreme disruption of the socio-technical environment. This situation creates a complex, unstable nonlinear environment. The chaotic environment is subject to two major forces—emergent and convergent. The ability of these forces to self-organize, adapt, cooperate, and integrate is dependent upon capacity of the communications system.

This thesis argues that during a response to catastrophic events, the most vital task is the reestablishment of a communications system. However, despite acknowledging the importance of communications, current U.S. plans and strategy concerning communications are insufficient, fragmented, and disorganized. The 2011 National Level Exercise, New Madrid earthquake, tested communications inoperability and redundancy then moved on to the traditional focus of crisis response practitioners (operations, planning, logistics, and to a lesser extent, administration).

Incident Command System (ICS) is over 40 years old and requires changes to support communications efforts adequately. ICS does not provide for a communication leader with a voice on the general staff; furthermore, communication and information responsibilities are fragmented. A catastrophic event requires intensive ICT efforts. ICS does not recognize the synergistic energies of combining these efforts. Finally, the ICS model does not acknowledge that information and communications technology (ICT) is a highly technical discipline that requires very specific resources, understanding, and training within this complex, dynamic, and accelerating field.

All the official literature acknowledges that communication is a problem during crisis response. There is no overall communication strategy that clearly and

comprehensively emphasizes the essential nature of reestablishing communication networks and managing network evolution and massive information flows that result from the intersection of emergent and convergent forces.

One solution would be to create an information and communication section within ICS. This section would be responsible for the implementation of the communications strategy. To achieve the goals the section should deploy multiple independent rapid technology assessment teams (RTAT). This form of structural distributed management system would allow the ICS model to maintain its traditional structure while benefiting from an agile open-system strategy in response to ICT needs.

A crisis response is a highly unstable, social-environmental, nonlinear (chaotic) event. The ability to control chaos is limited, but the environment will eventually become stable as response blindly and methodically restores the socio-technical networks and satisfies the basic needs of the affected population. The goal should be to contract that chaotic period, limiting human suffering and economic loss.

The two most promising methods for controlling chaos are the careful use of perturbations and changing the "orbits" within a nonlinear system. Rapid intervention using mobile ICT teams is not a new idea.[352] The UN and FEMA are both attempting to use this concept. During Hurricane Sandy, the FEMA Disaster Emergency Communications unit sent out small mobile teams to assess communications needs and focus attention of both response resources and private industry to reestablish communications.[353] This type of ICT intervention uses small perturbations; the teams are solely focused on the communication and information needs of the response.

Establishing network connectivity creates natural social attractors that will allow self-organization and adaption of emergent forces and provide a mechanism for cooperation and collaboration with convergent forces. By extending the network, the natural centers of organization will emerge, and following the properties of preferential attachments, they will become hubs or centers for response organization. These hubs,

[352] Fritz, and Mathewson, *Convergence Behavior in Disasters*.

[353] Kielty, and MacLean, "We Know You Can Hear Us."

forming many individual basins within the affected region, are examples of orbits of attraction. Using the concepts of network sciences and new, inexpensive technologies, hubs can now be predicted and promoted, accelerating social linkage.

The dynamic network maps from Haiti and Katrina demonstrate that the hubs of connectivity and centrality change as needs change. The needs of the response do not follow a hierarchical model. These changes must be anticipated and addressed before traffic (urgent requests for assistance) overwhelms those specific sectors that provide particular services and resources. Management is better handled by a unified ICT effort that is not simply a support function for the other sections.

Communications and information management should not be relegated to a support of the response effort. It is a crucial, foundational function that impacts every part of the response, for better or for worse. As the memories of Hurricane Katrina fade, the impetus and urgency for improvement in crisis response wanes. This is a natural cycle with respect to policy making. Currently, the national response plans are without a coherent and comprehensive communications strategy. There is a failure to appreciate the centrality of communications and its role in binding the emergent and convergent forces and combatting chaos. Crisis response organization must be changed to acknowledge the essential nature of communications formally and place an emphasis on supporting communications as a strategic objective. Communications is not a support function, but a foundational system that must be achieved and maintained for crisis response to function efficiently.

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APPENDIX A. KATRINA NETWORK DATA

Data sources:

- Hurricane Katrina network data provided by Louise Comfort of the University of Pittsburg—Center for Disaster Management
- Comfort, Louise K. and Haase, Thomas W. (2006). "Communication, Coherence, and Collective Action: The Impact of Hurricane Katrina on Communications Infrastructure" (Graduate School of Public and International Affairs, University of Pittsburgh. Published in *Public Works Management and Policy*, 2006, Vol. 11:1), pp. 1–16.
- Hurricane Katrina network data provided by Naim Kapucu of the University of Central Florida, Department of Public Administration
- Article written for Administration and Society by Naim Kapucu, Tolga Arslan and Matthew Lloyd Collins. (2010). "Examining Intergovernmental and Interorganizational Response to Catastrophic Disasters: Toward a Network-Centered Approach."
- Butts, Carter T., Acton, Ryan M., & Marcum, Christopher M. (2012). Interorganizational Collaboration in the Hurricane Katrina Response (JoSS Vol:13, February 2012), pp. 1–36.
- Hurricane Katrina data publically available at http://www.cmu.edu/joss/content/articles/volume13/katrina_1.0.tar.gz

A. Data Collection Methods

Comfort, Louise K. and Haase, Thomas W. (2006). "Communication, Coherence, and Collective Action: The Impact of Hurricane Katrina on Communications Infrastructure" (Graduate School of Public and International Affairs, University of Pittsburgh. Published in *Public Works Management and Policy*, 2006, Vol. 11:1), pp. 1–16.

> Looking for a daily record of actions undertaken to cope with this event, we conducted a content analysis of news reported in the *Times Picayune,* the major New Orleans newspaper that continued publication throughout the disaster, albeit from Baton Rouge. Through the content analysis, we identified all organizations that participated in the response operations to Hurricane Katrina and the interactions among them. This set of organizations made up a response system of organizations seeking to protect lives, protect property, and maintain continuity of operations within the affected area. We used these data to characterize the response

> network and to analyze the relationships among them, using the software program, UCINET (Comfort et al., 2006 p. 6).

Naim Kapucu, Tolga Arslan, and Matthew Lloyd Collins. (2010). "Examining Intergovernmental and Interorganizational Response to Catastrophic Disasters: Toward a Network-Centered Approach."

> In this study, content analysis of news reports, government documents, and after-action reports was conducted. The main goal of the content analysis was to find the performance of intergovernmental and interorganizational response to the catastrophic disasters in 2005. The study uses data from the content analyses of related news reports from the *New York Times*, *FEMA National Situation Reports* (FEMA, 2006), *Florida State Emergency Response Team (SERT) Situation Reports* (www.floridadisaster.org), *New Orleans City Situation Reports*, *Louisiana State Situation Reports*, *Mississippi State Situational Reports*, *The Federal Response to Hurricane Katrina: Lessons Learned* (Townsend, 2006), *Hurricane Katrina: A Nation Still Unprepared* (U.S. Senate, 2006), and the *U.S. House of Representatives Select Bipartisan Committee to Investigate the Preparation for and Response to Katrina: A Failure of Initiative* (2006).
>
> Network analysis was performed using the UCINET social network analysis program to assess the relationships among the organizations that responded to the catastrophic disasters. UCINET is a comprehensive software program for the analysis of social networks. (Kapucu et al., 2010, p. 231).

Butts, Carter T., Acton, Ryan M., and Marcum, Christopher M. (2012). "Interorganizational Collaboration in the Hurricane Katrina Response" (JoSS Vol:13, February 2012), pp. 1–36.

> The authors collected materials for this project by searching online sources for documents related to the Hurricane Katrina response. Sources were identified by multiple methods, including: use of commercial search engines (e.g., Google); direct browsing of state, local, and federal websites (as well as sites of other organizations identified as potential responders); references to websites in online discussion groups, mailing lists, or web-based information portals; and suggestions from practitioners in the emergency management community. (Butts et al., 2012, p. 4)

B. Hurricane Katrina Metrics

Participating Organizations

Jurisdictional Percentage Breakdown	Butts et al. (2012) 8/23–9/5	Comfort & Haase (2006) 8/27–9/19	Kapucu et al. (2010) 8/25–9/25
International	8.3	3.7	-------
Federal	17.1	31.4	9
Regional	2.9	6.2	-------
Interstate	1.3	-------	-------
State	38	17	27
Sub-Regional	------	6.2	-------
County	10	13.6	23
Local	15.7	21.9	11
City	5.7	-------	-------
Non-Profit	-------	-------	14
Private	-------	-------	16
Total Percentage	100[354]	100	100
Numbers of Organizations	1577	535	580

[354] Butt et al. (2012), p, 8. Addition of 1.1 percent of data missing jurisdictional equals 100 percent.

Degree Centrality

Butts, Acton and Marcum (2012)

Degree Centrality	Degree	Nrm Degree
M	1.087	0.069
SD	3.143	0.199
SUM	1714.000	108.756
Variance	9.876	0.040
SSQ	17438.000	70.208
MCSSQ	15575.099	62.707
Euc Norm	132.053	8.379
Min	0.000	0.000
Max	45.000	2.855
Network Centralization	2.790	
Heterogeneity	0.590	
Normalized	0.530	

Comfort & Haase (2006)

Degree Centrality	Degree	Nrm Degree
M	2.422	0.969
SD	3.825	1.530
SUM	608.000	243.200
Variance	14.634	2.342
SSQ	5145.000	823.360
MCSSQ	3673.235	587.718
Euc Norm	71.736	28.694
Min	1.000	0.400
Max	42.000	16.800
Network Centralization	15.960	
Heterogeneity	1.390	
Normalized	1.000	

Kapucu, Arslan and Collins (2010)

Degree Centrality	Degree	Nrm Degree
M	1.821	0.314
SD	6.266	1.080
SUM	1058.000	182.414
Variance	39.262	1.167
SSQ	24738.000	735.375
MCSSQ	22811.385	678.103
Euc Norm	147.283	27.118
Min	0.000	0.000
Max	84.000	14.483

Network Centralization	14.22
Heterogeneity	2.21
Normalized	2.04

Closeness Centrality

Closeness Centrality Measures

Butts, Acton and Marcum (2012)

Closeness Centrality	Closeness	nCloseness
M	35.911	2.279
SD	54.256	3.443
Sum	56632.098	3593.407
Variance	2943.752	11.852
SSQ	6676027.500	26878.541
MCSSQ	4642296.500	18690.479
Euc Norm	2583.801	163.947
Min	0.000	0.000
Max	212.283	13.470

Kapucu, Arslan and Collins (2010)

Closeness Centrality	inFarness	outFarness	inCloseness	outCloseness
M	315959.656	3159595.656	0.185	0.192
SD	22,697.51	52,856.90	0.013	0.05
Sum	183,572,560.00	183,572,560.00	107.213	111.494
Variance	515,177,120.00	2,793,851,648.00	0.000	0.002
SSQ	58,300,838,182,912.00	59,624,745,074,688.00	19.889	22.837
MCSSQ	299,317,919,744.00	1,623,227,760,640.00	0.105	1.441
Euc Norm	7,635,498.50	7,721,706.00	4.460	4.779
Min	289,673.00	175,273.00	0.172	0.172
Max	336,980.00	336,980.00	2.000	0.331

Comfort & Haase (2006)

Closeness Centrality	Farness	nCloseness
M	26864.047	1.301
SD	19760.900	0.504
Sum	6742876.000	326.587
Variance	390493184.000	0.254
SSQ	279154720768.000	488.647
MCSSQ	98013790208.000	63.711
Euc Norm	528350.938	22.105
Min	15493.000	0.400
Max	62500.000	1.614

Betweenness

Butts, Acton and Marcum (2012)

Betweenness Centrality	Betweenness	nBetweenness
M	319.286	0.026
SD	2488.452	0.201
SUM	503514.000	40.570
Variance	6192392.000	0.040
SSQ	9926167552.000	64.442
MCSSQ	9765402624.000	63.398
Euc Norm	99630.156	8.028
Min	0.000	0.000
Max	63200.012	5.092

Network Centralization	5.070

Comfort & Haase (2006)

Betweenness Centrality	Betweenness	nBetweenness
M	205.430	0.660
SD	739.320	2.375
SUM	51562.000	165.664
Variance	546594.438	5.642
SSQ	147787808.000	1525.527
MCSSQ	137195200.000	1416.186
Euc Norm	12156.801	39.058
Min	0.000	0.000
Max	8065.853	25.914

Network Centralization	15.360

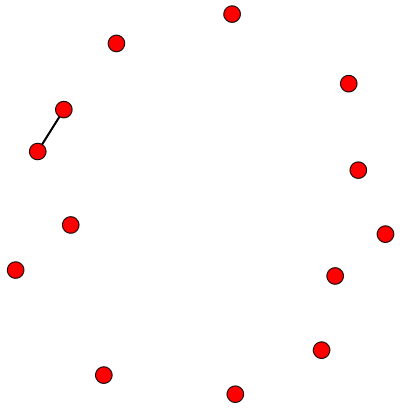
Kapucu, Arslan and Collins (2010)

Betweenness Centrality	Betweenness	nBetweenness
M	78.267	0.023
SD	569.981	0.170
SUM	45473.000	13.541
Variance	324878.875	0.029
SSQ	192313648.000	17.053
MCSSQ	188754624.000	16.737
Euc Norm	13867.720	4.130
Min	0.000	0.000
Max	8694.527	2.589
Network Centralization	2.570	

C. Dynamic Network Maps August 24 to September 5, 2005

Generated form the Butts, Acton, and Marcum data.

KATRINA: 8/24/2005



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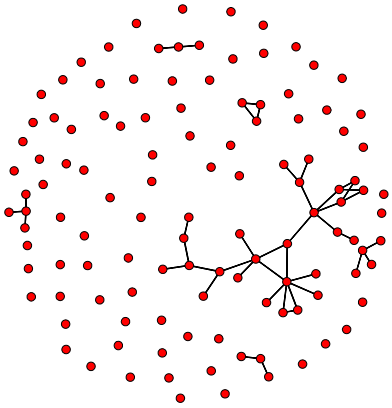
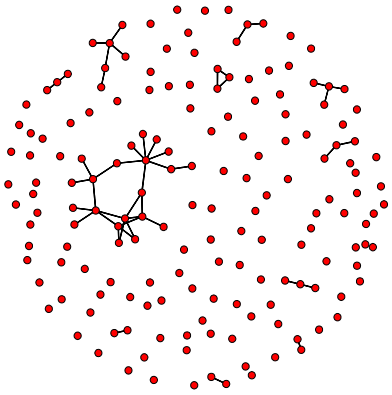


KATRINA: 8/26/2005



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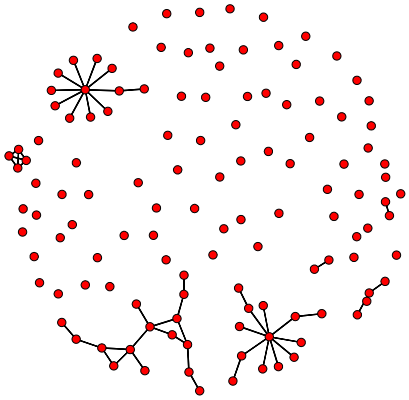
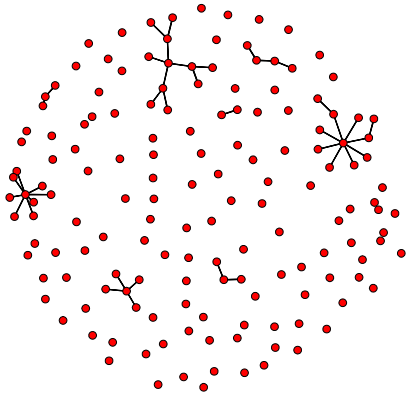
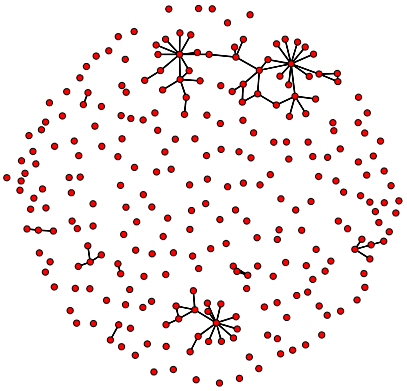


KATRINA: 8/28/2005/2005



KATRINA: 8/29/2005



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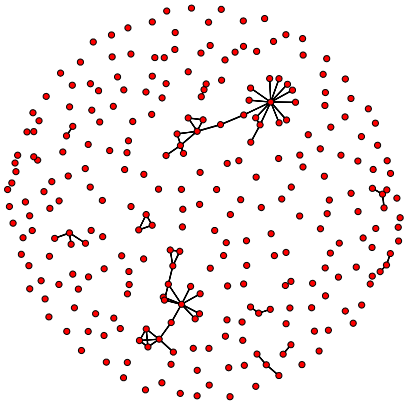
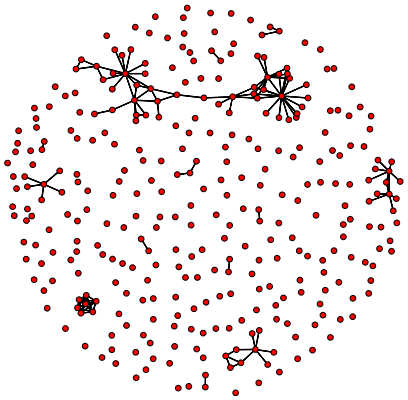
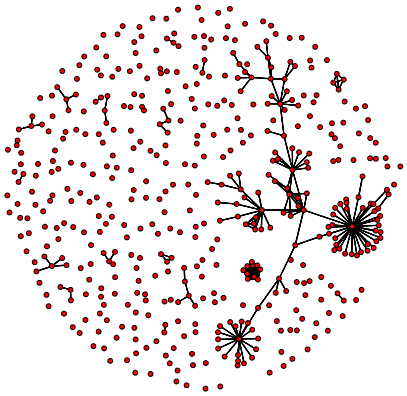


KATRINA: 8/31/2005



KATRINA: 9/1/2005



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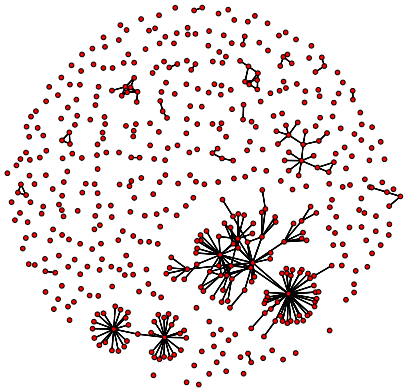

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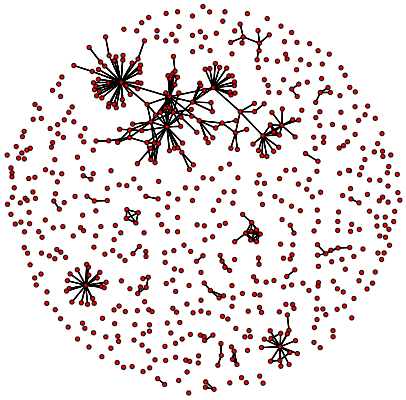

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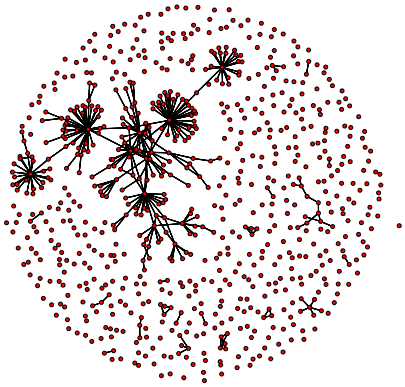
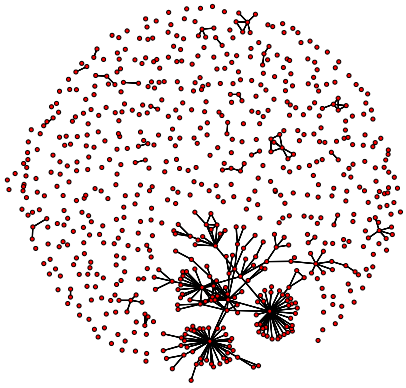


KATRINA: 9/5/2005



D. Aggregate Maps

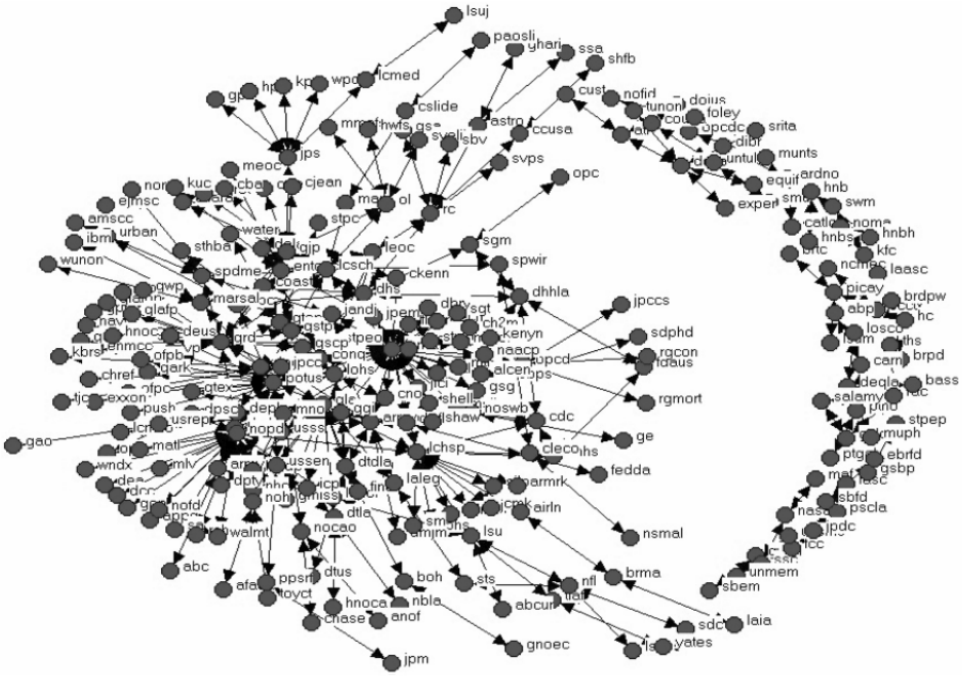


Figure 1 Hurricane Katrina Network of interacting Organizations, August 27–September 19, 2005 (Comfort et al., 2006, p. 8)

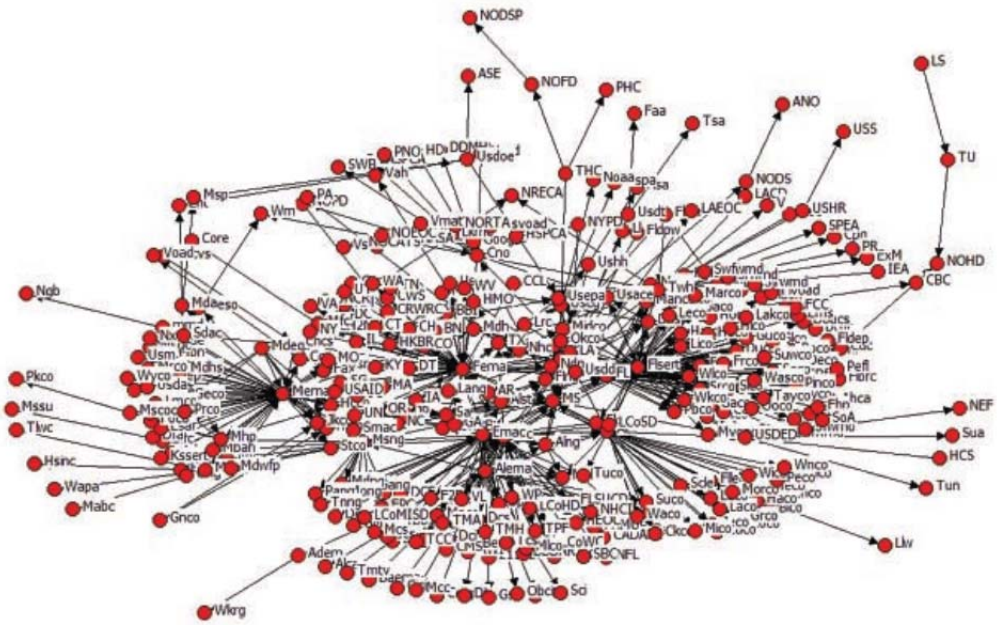


Figure 2 Interorganizational networks in response to Hurricane Katrina and Rita (Kapucu et al., 2010, p. 234)

E. Organization Names

Legend of Organizations from Comfort and Hasse (2006 p. 13)

Acronym	*Organization*	*Acronym*	*Organization*
Abc	American Broadcasting Corporation	chref	Chalmette Refining LLC
Abcur	Ascension Baptist Church	cjean	City of Jean Lafitte
Abp	Associated Branch Pilots	ckenn	City of Kenner
Afaca	Air Force Academy	cleco	Cleco Corp
Airln	Airlines	cmk	Clarence M. Kelly & Associates
Alcen	Westwego Alario Center	cno	City of New Orleans
Amscc	Arthur Monday Senior Citizens Center	coast	United States Coast Guard
		cong	United States Congress
Anof	America's New Orleans Fund, Inc.	cousa	Conference USA
Appd	Assumption Parish Police Department	cslide	Government of Slidell
		cust	United States Customs Agency
Ardno	Archdiocese of New Orleans	cwestw	City of Westwego
Armrk	Aramark	dala	Department of Administration, Louisiana
Army	United States Army		
Armycp	Army Corps of Engineers	dbry	Dewberry Technologies
Astro	Houston Astrodome	dcc	Dixon Correctional Center
Atf	Bureau of Alcohol, Tobacco, Firearms and Explosives	dea	Drug Enforcement Agency, United States
Bass	Bass Enterprises	dela	Department of Education, Louisiana
Bech	Bechtel National, Inc.	depla	Department of Emergency Preparedness, Louisiana
Boh	Boh Bros. Construction Co.		
Brdpw	Baton Rouge Department of Public Works	deqla	Department of Environmental Quality, Louisiana
Brma	Baton Rouge Metropolitan Airport	deus	Department of Education, United States
Brpd	Baton Rouge Police Department		
Brtc	Baton Rouge Technology Center	dhhla	Department of Health and Hospitals, Louisiana
Carn	Carnival Corporation		
Catlc	Catholic Life Center	dhhs	Department of Health and Human Services, United States
Cba	Columbia Broadcasting Service		
Ccusa	Catholic Charities USA	dhs	Department of Homeland Security, United States
Cdc	Centers of Disease Control and Prevention	dibr	Diocese of Baton Rouge
Cgret	City of Gretna	dmjm	DMJM Harris-AECOM
ch2m	CH2M Hill	dnrla	Department of Natural Resources, Louisiana
Chara	City of Harahan		
Chase	Chase Bank	dod	Department of Defense, United States
Dpty	Democratic Party		
Dtdla	Department of Transportation and Development, Louisiana	dojla	Department of Justice, Louisiana
		dojus	Department of Justice, United States
Dtla	Department of the Treasury, Louisiana	dpsc	Department of Public Safety and Corrections, Louisiana
Dtus	Department of Transportation, United States	dpsc	Drug Enforcement Agency, United States
Dwfla	Department of Wildlife and Fisheries, Louisiana	gmiss	Governor of Mississippi
		gnoec	Greater New Orleans Expressway Commission
Ebrfd	East Baton Rouge Parish Fire Department	gop	Orleans Parish
Ejmsc	E.J. Morris Senior Center	gpd	Gretna Police Department
Enmcc	Ernest N. Morial Convention Center	gpp	Plaquemines Parish
Entgy	Entergy Corp.	grd	National Guard
Equif	Equifax	gsa	Government of Saudi Arabia
Exper	Experian	gsbp	St. Bernard Parish
Exxon	Exxon Mobil Corp	gscp	St. Charles Parish
Fcc	Federal Communications Commission	gsg	City of St. Gabriel
		gsjp	St. John Parish
Fdaus	Food and Drug Administration, United States	gslcm	County of St. Louis, Missouri
		gstp	St. Tammany Parish
Fedda	Federal Drug Administration	gtep	Terrebonne Parish

Fema	Federal Emergency Management Agency
Fina	Fertility Institute of New Orleans
Flour	Fluor Corp
Foley	Foley & Judell
Gao	General Accountability Office
Gark	State of Arkansas
Ge	General Electric
Gebrp	East Baton Rouge Parish
Ggi	City of Grand Isle
Ghari	County of Harris, Texas
Gjp	Jefferson Parish
Gla	Governor of Louisiana
Glafop	Lafourche Parish
Glafp	Lafayette Parish
Dpty	Democratic Party
Dtdla	Department of Transportation and Development, Louisiana
Jps	Jefferson Parish Sheriff's Office
Kbrs	Kellogg Brown & Root Services
Kenyn	Kenyon International Emergency Services
Kfc	Kentucky Fried Chicken
Kpd	Kenner Police Department
Kuc	Kentucky Utility Crew
Laasc	Louisiana Arts and Science Center
Laia	Louis Armstrong International Airport
Laleg	Louisiana Legislature
Lasc	Louisiana Supreme Court
Lchsp	Local Hospitals, Medical Care
Lcmed	Local Media
Lcmno	Legal Council for the Mayor of New Orleans
Lcsch	Local Schools, K-12
Leoc	Louisiana Emergency Operations Center
Lspol	Louisiana State Police
Lsu	Louisiana State University
Lsubs	Louisiana State University Board of Supervisors
Lsudp	Louisiana State University Department of Psychiatry
Lsuj	Louisiana State University School of Journalism
Lsum	Louisiana State University, Manship School for Mass Communications
Maf	Michoud Assembly Facility
Mar	United States Marines
Marsal	Alvarez & Marsal
Matl	Mayor of Atlanta
Meoc	Mississippi Emergency Operations Center
Mlv	Mayor of Las Vegas
Mmefs	Marrero Marrero-Estelle Fire Station
Mno	Mayor of New Orleans
Motor	Motorola, Inc
Msli	Mayor of Slidell
Potus	Office of the President of the United States
Ppsrf	Plaquemines Parish Sheriff Office
gtex	State of Texas
hnb	Hibernia National Bank
hnbh	Hibernia National Bank Operation Center Houston
hnbs	Hibernia National Bank Operation Center Shreveport
hnoc	Historic New Orleans Collection
hnoca	Harrah's New Orleans Casino
hpd	Harahan Police Department
hwfs	Herb Wallace Fire Station
ibm	International Business Machines
icp	Illinois Conservation Police
jandj	J&J Maintenance, Inc.
jlci	Joint Legislative Committee on Insurance
jpcc	Jefferson Parish Correctional Center
jpccs	Jefferson Parish Clerk of Courts
jpdc	Jefferson Parish District Court
jpem	Jefferson Parish Emergency Management
jpm	Jefferson Parish Morgue
mtf	Metairie Transit Facility
munts	Munters
muph	Murphy Oil Corp
naacp	National Association of the Advancement of Colored People
nasa	National Aeronautical and Space Administration
navy	United States Navy
nbc	National Broadcasting Corporation
nbla	National Bond Lawyers Association
ncmec	National Center for Missing and Exploited Children
ndms	National Disaster Medical System
nfl	National Football League
nhc	National Hurricane Center
nocao	New Orleans City Attorney Office
nofd	New Orleans Fire Department
nofid	New Orleans Finance Department
noh	New Orleans Hornets
noma	New Orleans Museum of Art
noms	New Orleans Mission
nopd	New Orleans Police Department
noswb	New Orleans Sewerage & Water Board
nsmal	North Shore Square Mall
ofpb	Office of Former President Bush
ofpc	Office of Former President Clinton
Ol	Operation Life-Line Depot
opc	Orleans Parish Coroner
opcd	Orleans Parish Communications District
opcdc	Orleans Parish Civil District Court
opp	Orleans Parish Prison
paosli	Public Affairs Office, Slidell
phs	United States Public Health Service
picay	*Times-Picayune*
srita	St. Rita's Nursing Home
ssa	Social Security Administration
ssc	Stennis Space Center
sthba	St. Tammany Parish Home Builders Association

Pscla	Public Service Commission, Louisiana	stpc	St. Tammany Parish Council
Ptgal	Port of Galveston	stpeo	St. Tammany Parish Emergency Operations Center
Ptno	Port of New Orleans	stpep	St. Tammany Parish Office of Emergency Preparedness
Push	Rainbow/PUSH	stpso	St. Tammany Parish Sheriff's Office
Rac	Regional Assistance Center	sts	New Orleans Saints
Rc	American Red Cross	svelib	St. Ville Elementary Library
Rgcon	Register of Conveyances	svps	St. Vincent de Paul Society
Rgmort	Recorder of Mortgages	swm	Southwinds Motel
Rshot	Royal Sonesta Hotel	ths	The Humane Society
Rta	Regional Transit Authority	tiaf	Tiger Athletic Foundation
Sa	Sports Authority	tjc	TJC Engineering, Inc
Salamy	Salvation Army	toyct	Houston's Toyota Center
Sbem	St. Bernard Emergency Management	tunon	TransUnion
Sbfd	St. Bernard Parish Fire Department	unmem	University of Memphis
Sbps	St. Bernard Parish Sheriff Office	unsms	University of Southern Mississippi
Sbv	Southern Baptist Volunteers	untul	Tulane University
Scctx	Shelter in Corpus Christi Texas	urban	Urban League
Sdc	Superdome Commission	usrep	United States House of Representatives
Sdphd	St. Bernard Port, Harbor and Terminal District	ussen	United States Senate
Sgm	St. Gabriel Morgue	usss	United States Secret Service
Sgt	Southgate Towers	vp	Office of the Vice President of the United States
Shaw	The Shaw Group, Inc	walmt	Wal-Mart (Tchoupitoulas Street)
Shell	Gulf Royal Dutch Shell, PLC	water	Coast Waterworks, Inc
Shfb	Second Harvest Food Bank	wndx	Winn-Dixie's Riverside Market Place
Silpd	Slidell Police Department	wpd	Westwego Police Department
Sm	ServiceMaster	wunon	Western Union
Smu	Southern Methodist University	yates	W.G. Yates & Sons Construction Co.
Spdme	SuperDome		
Spwir	Sprint Wireless		

APPENDIX B. HAITI NETWORK DATA

Dynamic Network Analysis—Earthquake Haiti

Analysis of the Haiti response network uses studies conducted by the University of Pittsburgh—Center for Disaster Management. The analysis of the Haiti networks relies on the statics generated by the studies. The studies are:

Group A

- Comfort, Louise K., Siciliano, Michael D., and Okada, Aya (2011b) Resilience, Entropy, and Efficiency in Crisis Management: The January 12, 2010, Haiti Earthquake"
- Comfort, Louise K., Siciliano, Michael D., and Okada, Aya (2012) Evolving Systems in Crisis Management: The January 12, 2010, Haiti Earthquake"
- Comfort, Louise K. and Okada, Aya (2013). "Emergent Leadership in Extreme Events: A Knowledge Commons for Sustainable Communities"

Group B

- Scheinert, Steve and Konstantinova, Ralitsa (2011). "Attempting a Knowledge Commons in the Field: the Response to the January 12th, 2010 Haitian Earthquake"
- Siciliano, Michael (2011). "The Use of Exponential Random Graph Models to Investigate the Micro-Level Processes of Inter- Organizational Network Formation"

The dynamic network map were generated for the working paper appendices by Scheinert and Konstantinova for the University of Pittsburg—Center for Disaster Management:

- Attempting a Knowledge Commons in the Field: the Response to the January 12th, 2010 Haitian Earthquake: Appendices

The following is the methodology used by Scheinert and Konstantinova for data acquisition and methods of analysis:

Data Sources

Regularly published during a disaster response, the reports stored on ReliefWeb and OneResponse[355] document the response as it actually occurred. In presenting the cluster system, OneResponse presents how the response is supposed to operate. That is, each cluster has a lead organization that coordinates the actions of the cluster's membership, and UNOCHA provides organization, oversight, and coordination between the clusters. Cluster Meetings and documents record and communicate organizational and cluster actions to provide for real-time or near real- time communication and coordination between organizations. In actual performance, however, the response network may form and operate in ways that are very different from the plans. The representatives of a planned central agency may be unavailable at a key moment, allowing another organization to take over those duties, or coordination may collapse over clashes of personalities, are examples of two of many possible developments that change the system. The task of analyzing the response relies heavily on identifying what form the response actually took in practice. This allows the researcher to find and document strengths and weaknesses in the response by charting patterns of communication, coordination, and interaction. These data can be found in the documents on ReliefWeb and OneResponse, so that these documents allow an empirical analysis of the response.

The Center for Disaster Management (CDM) downloaded 139 situation reports ("sitreps") from ReliefWeb. Each situation was published by one of eleven different organizations. In its own sitreps, each organization focuses primarily on its own actions and observations, though few are entirely limited to the actions of the publishing organization. Nevertheless, due to that self- focus, building a responsibly accurate model of the response requires data from more than one organization. The CDM chose the set of organizations from experience in researching prior disasters, the official structure of the cluster system, and the local international organizations which focus on the Caribbean region, where Haiti is located. This list of organizations is:

[355] ReliefWeb and OneResponse are the largest portals for humanitarian information sharing. The portal is administered by UN OCHA.

- Caribbean Disaster Emergency Management Agency (CDEMA)
- UN Health Cluster
- UN Logistics Cluster
- United Nations Stabilization Mission in Haiti (MINUSTAH)
- UN Office for the Coordination of Humanitarian Affairs (UNOCHA)
- Pan-American Health Organization (PAHO)356
- United Nations Environmental Program (UNEP)
- United Nations Children's Fund (UNICEF)
- Office for Foreign Disaster Assistance (OFDA), USAID
- UN Water, Sanitation, and Hygiene (WASH) Cluster
- World Food Program (WFP)

Covering health and sanitation, logistics, food, vulnerable populations, security, and large-scale general aid operations, this list of organizations covers the primary aid tasks as well as the largest organizations. As mentioned above, the data collected covers the first three weeks following the earthquake, specifically 12 January 2010—1 February 2010, since this is the typical period of initial response before that response changes into long-term recovery (Comfort et al., 2011a, Comfort, 1999). This set of data, even with the self-focus of each organization's sitreps, covers the key organizations and structures of the response network.

To ensure the accuracy and validity of this data, CDM researchers, in conjunction with geologists from Vassar College and public health researchers from the University of Pittsburgh's School of Public Health, traveled to Haiti, following the earthquake, to observe the response directly. This trip took place from 2 May 2010 to 9 May 2010 and documented many aspects of the response and recovery efforts (Comfort et al., 2011a). The data collected on that trip will augment and extend the analysis from the network data collected from the sitreps.

356 PAHO is also the local division of the World Health Organization. Most actions by either PAHO or WHO were reported as having been done by PAHO/WHO or WHO/PAHO.

Methods of Analysis

Primary analysis was conducted by building and analyzing network models of the response system that developed during the first three weeks following the earthquake. By reviewing the text of the situation reports, they revealed what organizations did and which organizations interacted with which other organizations, and which worked alone. CDM researchers built the network models by recording these dyads and monads, observed in the sitreps discussed above, and then processing the dyads and monads through network analysis software[357] to reveal the patterns of action and interaction following the earthquake. CDM researchers made two versions of this network. The first was a static network that combined all the interactions observed in all of the sitreps into a single network for analysis. The second was a set of dynamic networks.

This set took each day during the first three weeks as a separate network, only coding for each day the dyads and monads that the researchers observed in the sitreps published on that day. This method shows the changes in the network over the course of the response. It shows how the network initially grew and developed.

With the network models made, network analysis includes several measures of the pattern of connections in the model that can be used to describe the model. Centrality measures can be used to determine the most well connected nodes, and so the most important nodes, in the network. Network centralization measures, including clustering coefficients, average distance, and network density describe the shape and amount of possible connections in the network that are actually observed. As a mirror to that, isolate counts record how many nodes are observed in the network but which lack any connections to any other nodes and network fragmentation records how many separate pieces there are in the network that are connected within that piece, but not to other pieces (Wasserman and Faust, 1994). Taking these measurements to describe the shape and characteristics of the network will show any gaps in the response system (Scheinert and Konstantinova, 2011 pp. 4–6).

[357] This paper uses two pieces of software at different times: *ORA, programmed at the CASOS Institute, at Carnegie Mellon University (Carley, 2011), is used for primary construction of the networks and taking dynamic measures. Most of the maps presented in this paper are made using NetDraw, which is the visualizer for UCINet, which is published by Analytic Technologies (Borgatti et al., 2002).

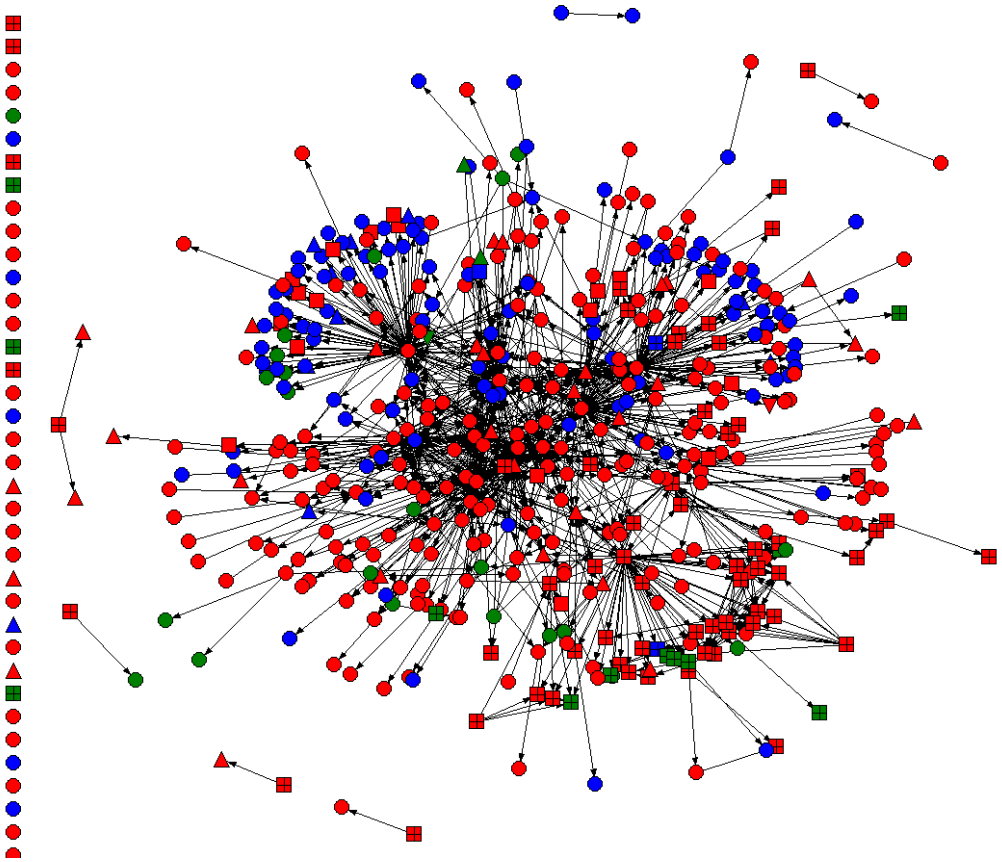


Figure 1. Static Network (Generated in UCINet; See Appendix 1 for Color and Shape Key)

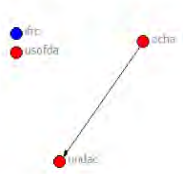
Appendices

Appendix 1: UCINet Network Map Key for Node Colors and Shapes

Organizational Source of Funding	
Source	Color
Public	
Private	
Non-Profit	

Organizational Jurisdiction	
Jurisdiction	Shape
Local	Square
Subdepartmental	Down Triangle
National	Up Triangle
Regional	Box
International	Circle

January 12th



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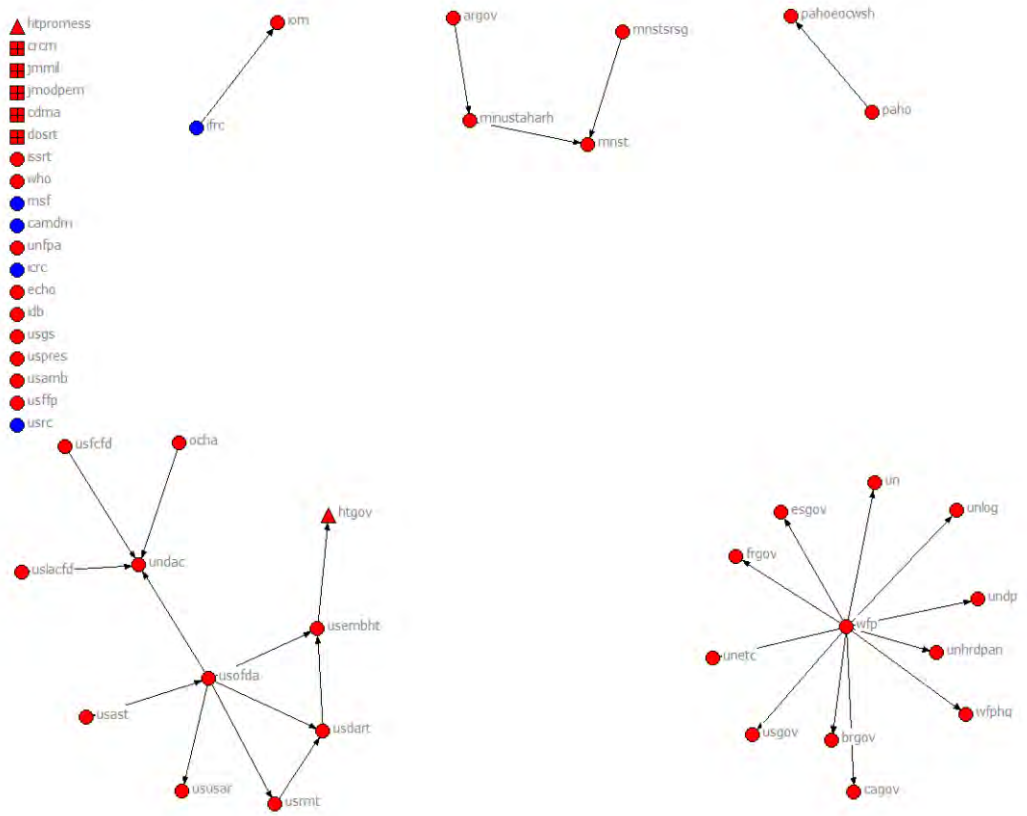

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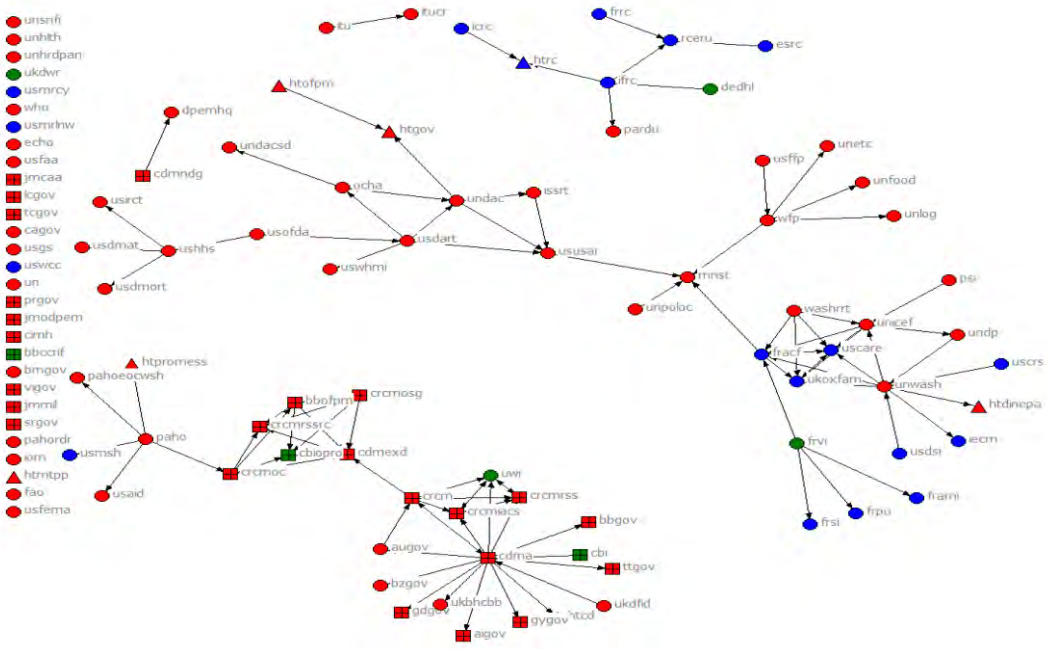

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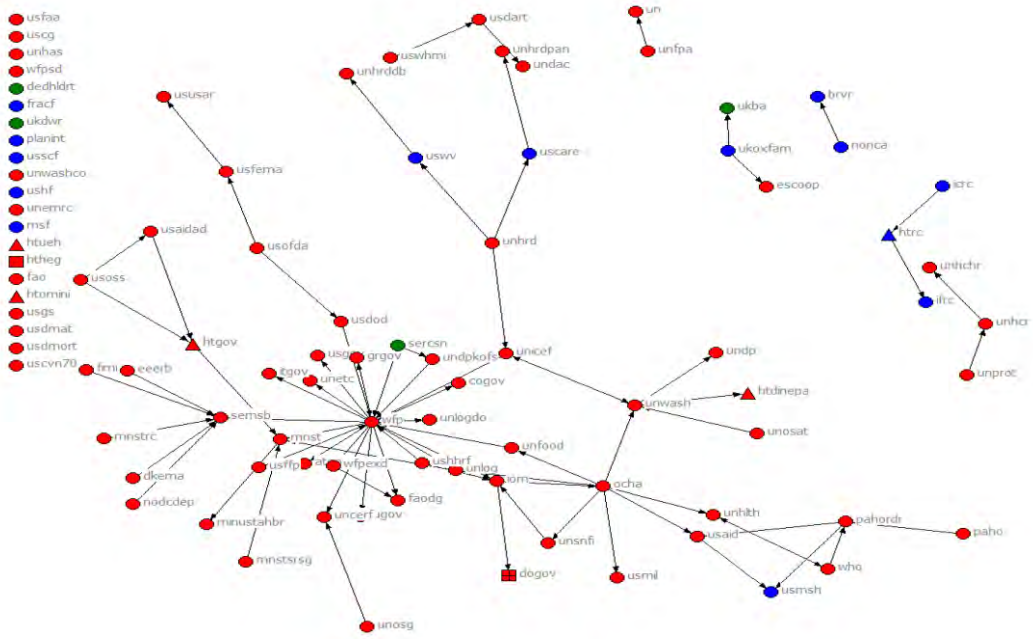

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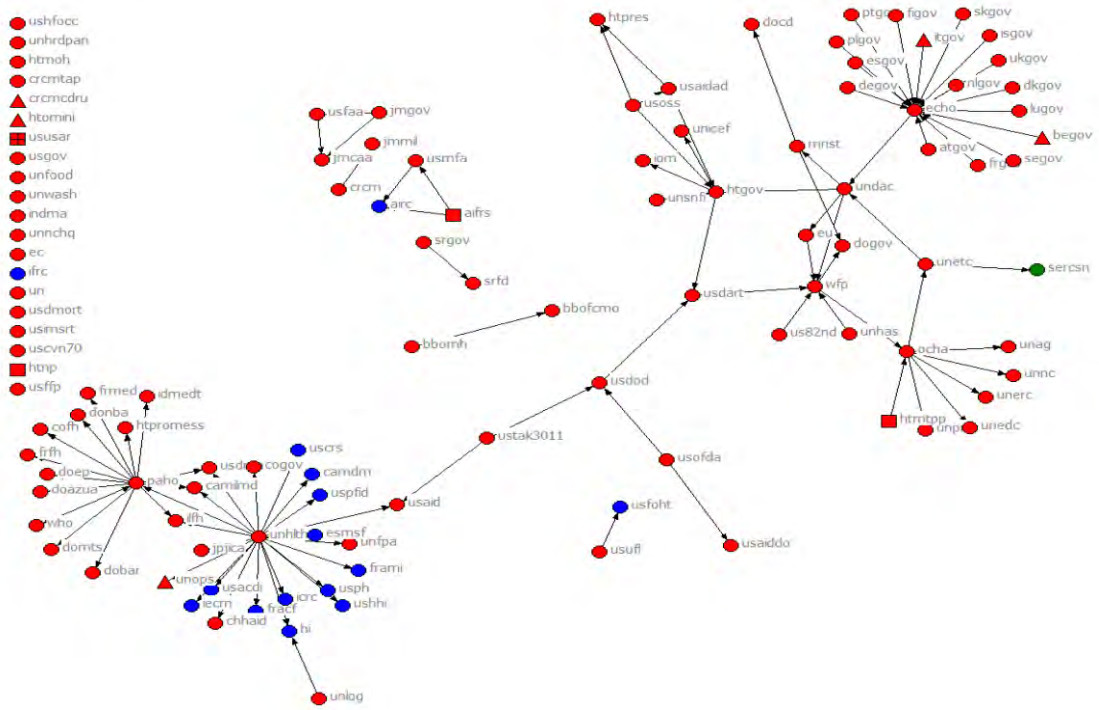

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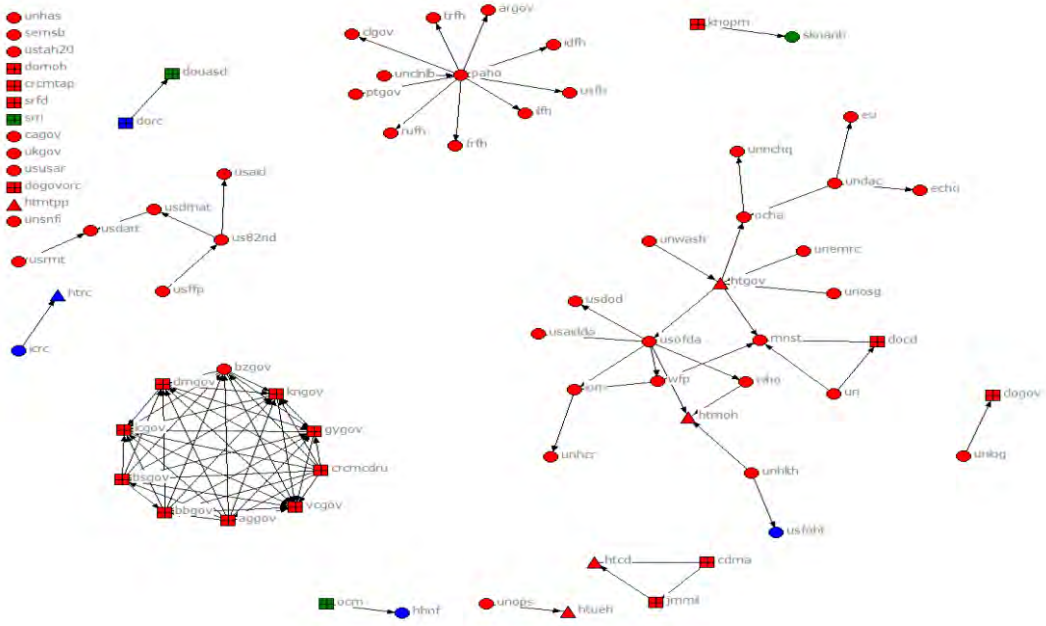

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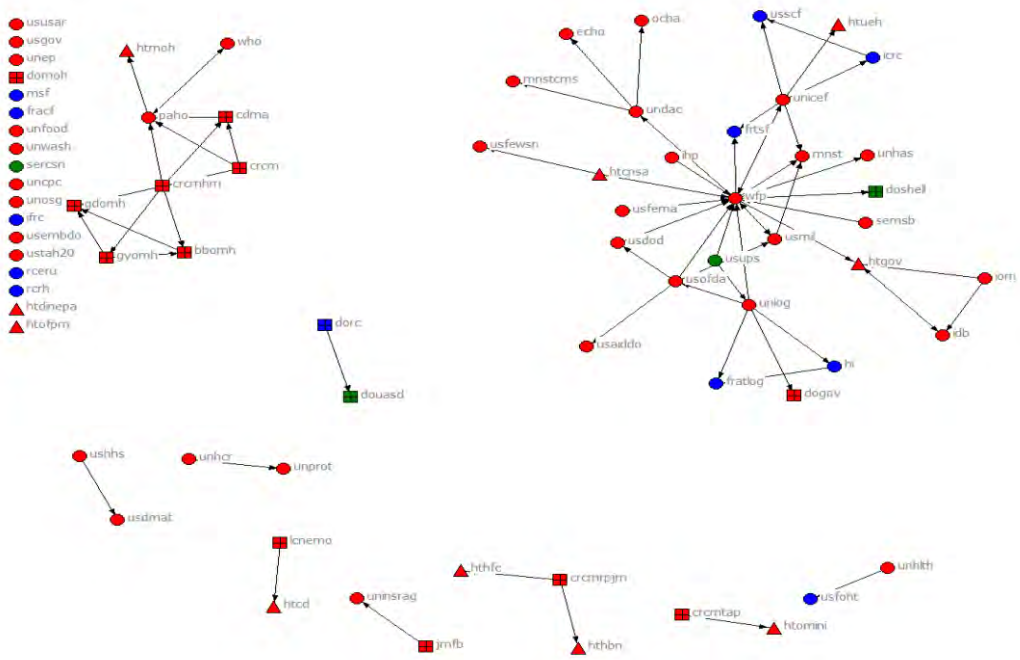

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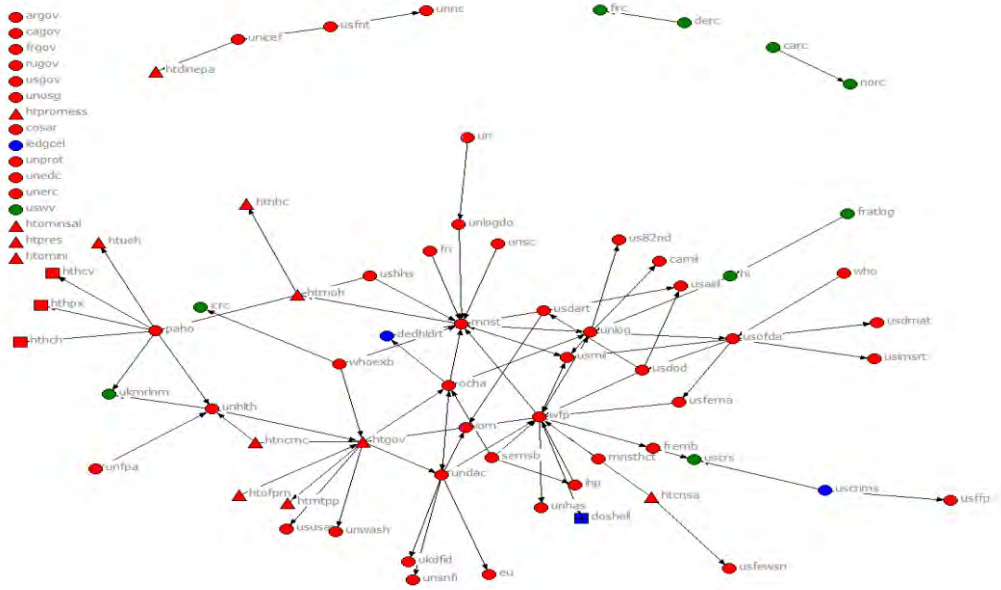

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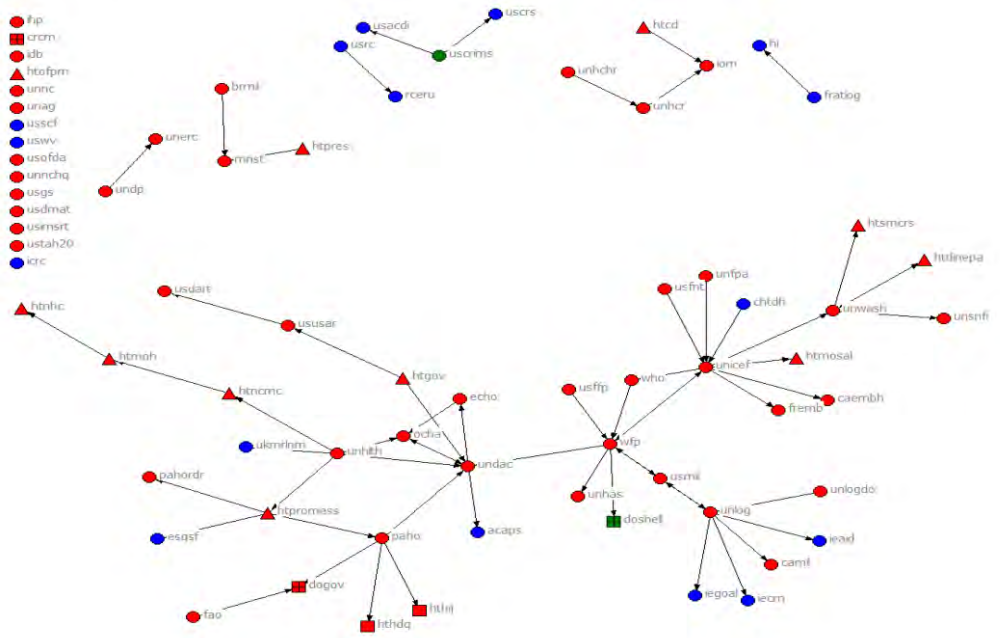

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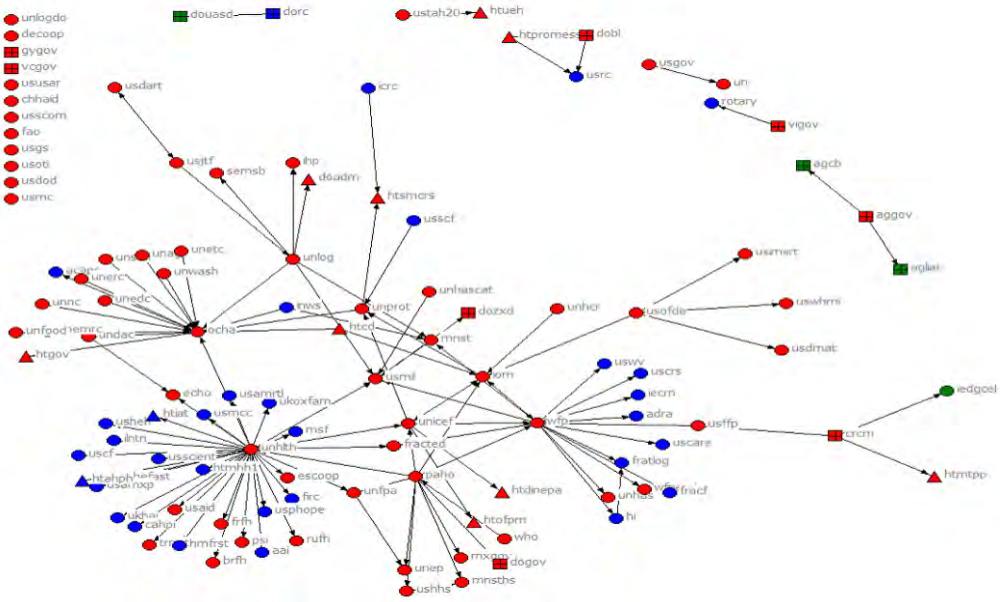

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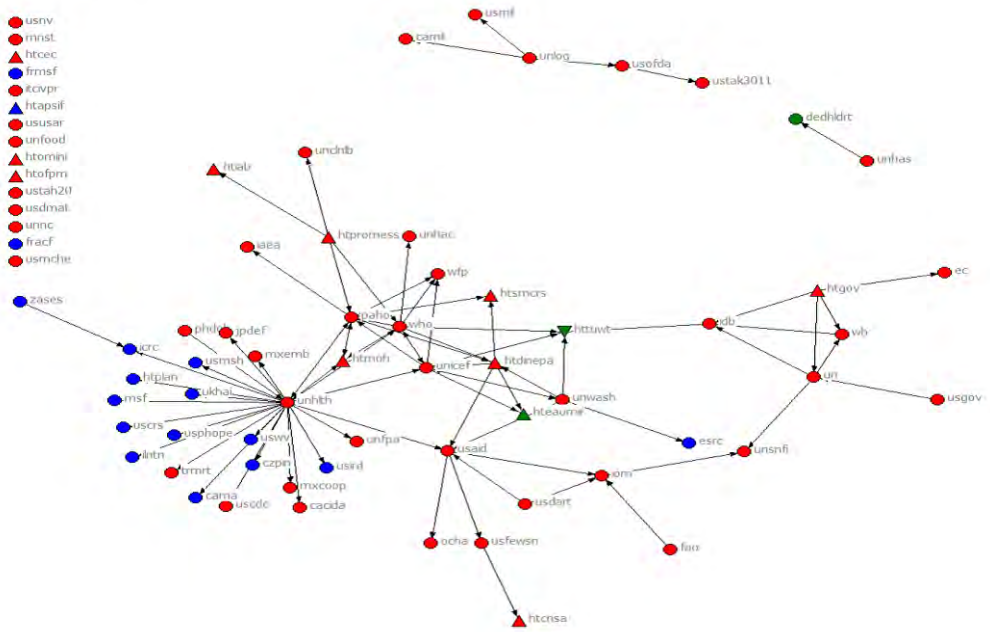

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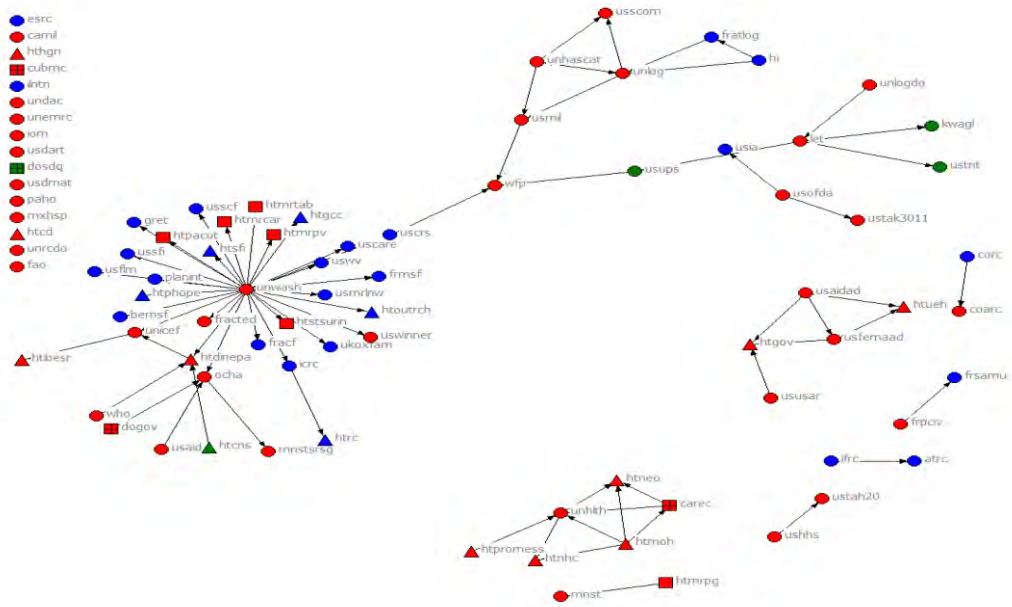

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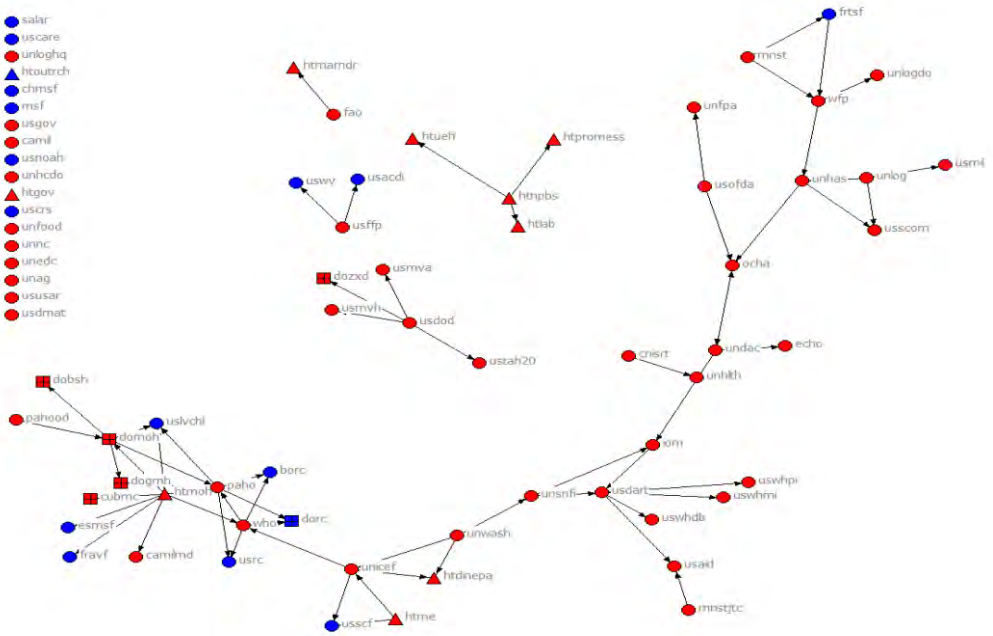

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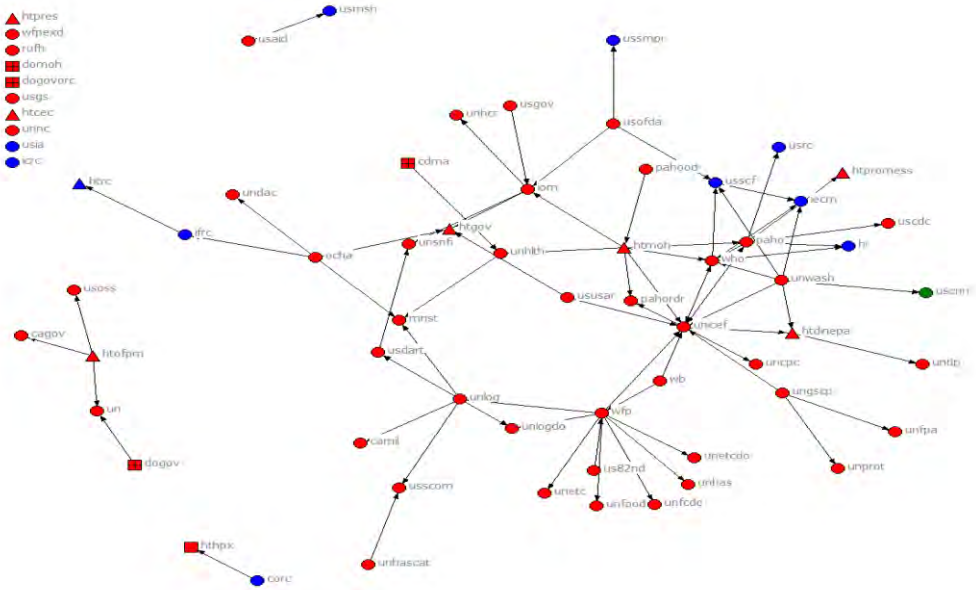

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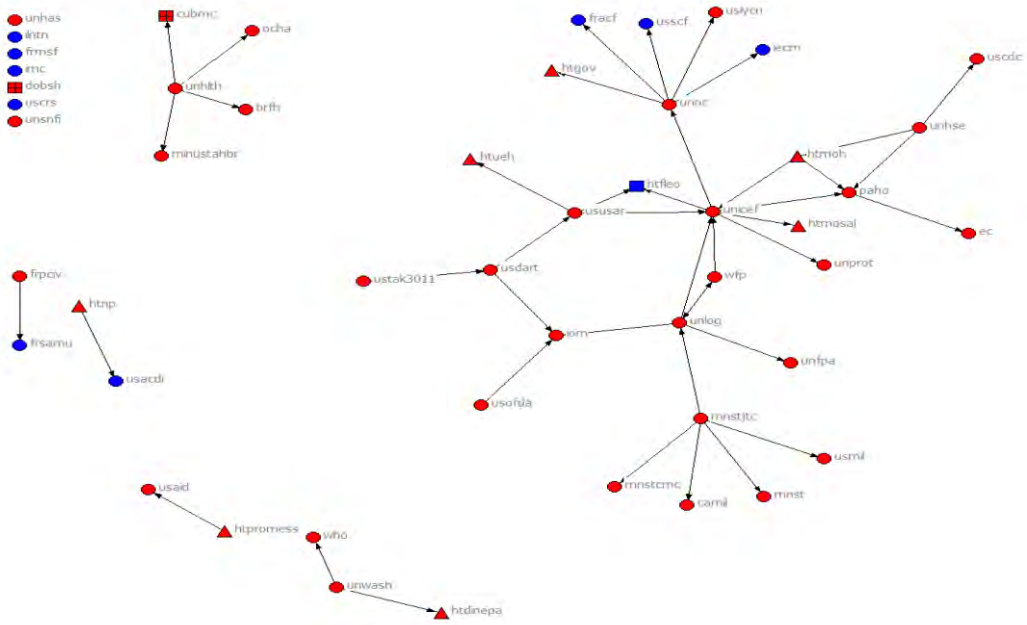

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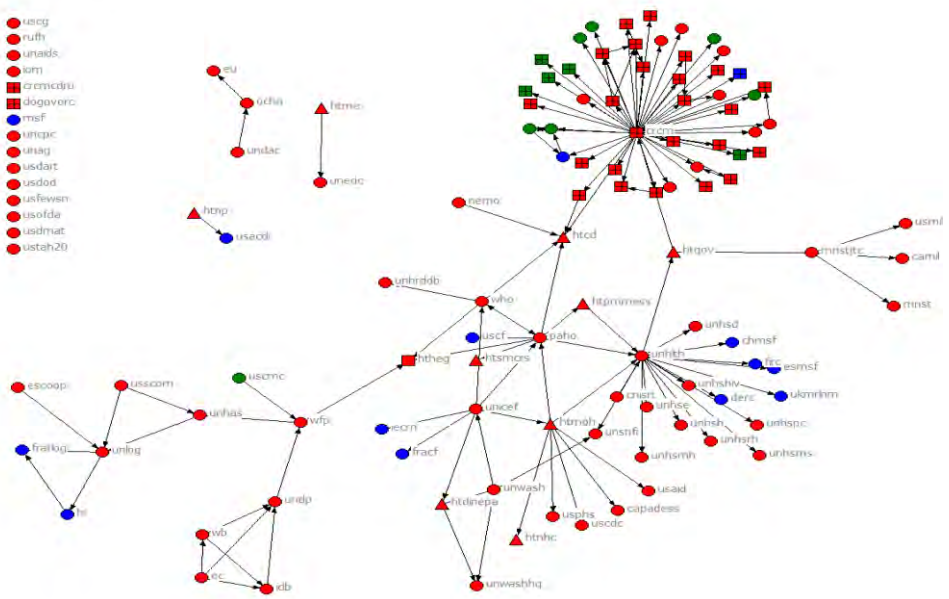

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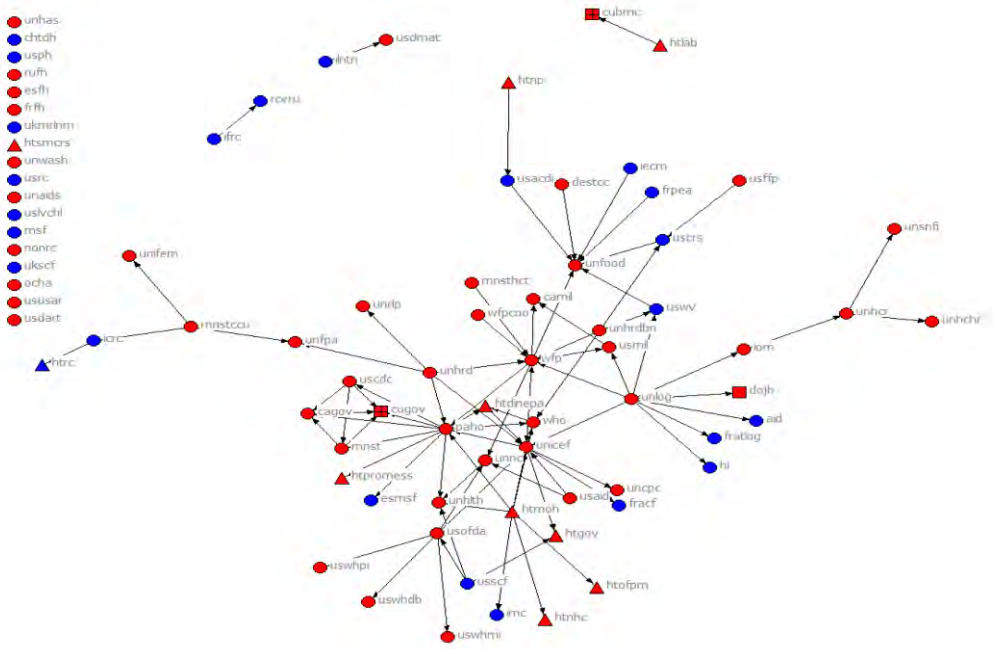

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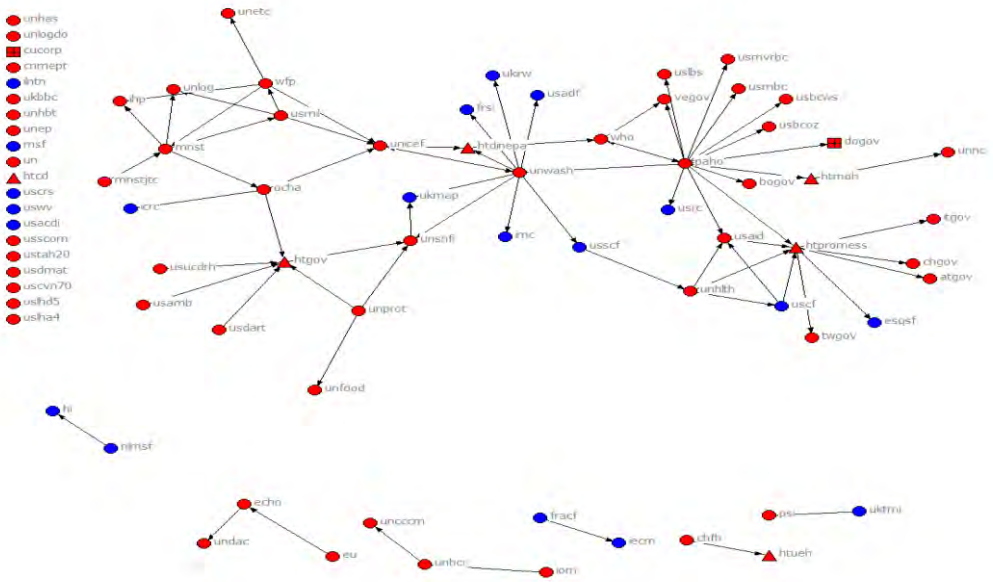

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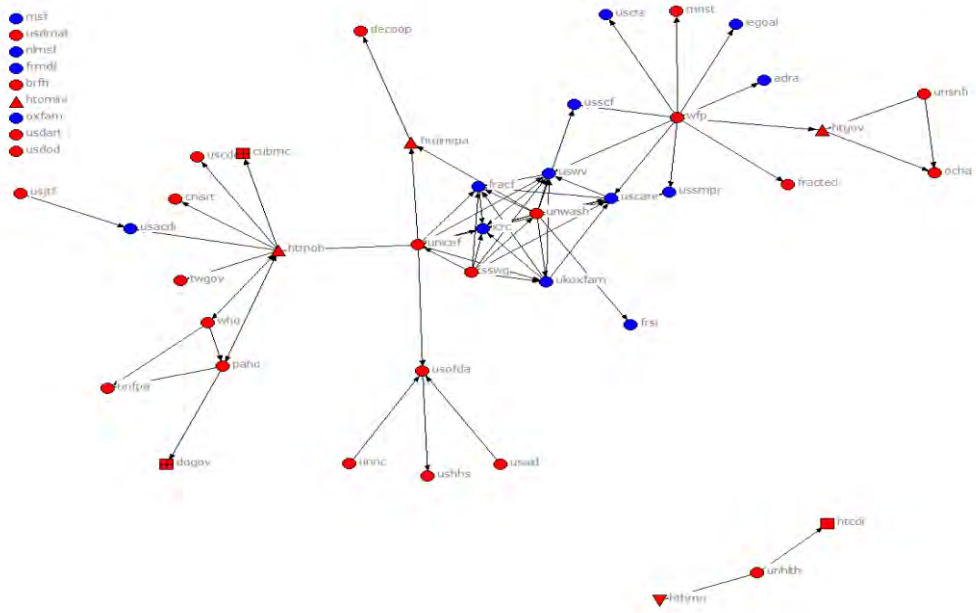

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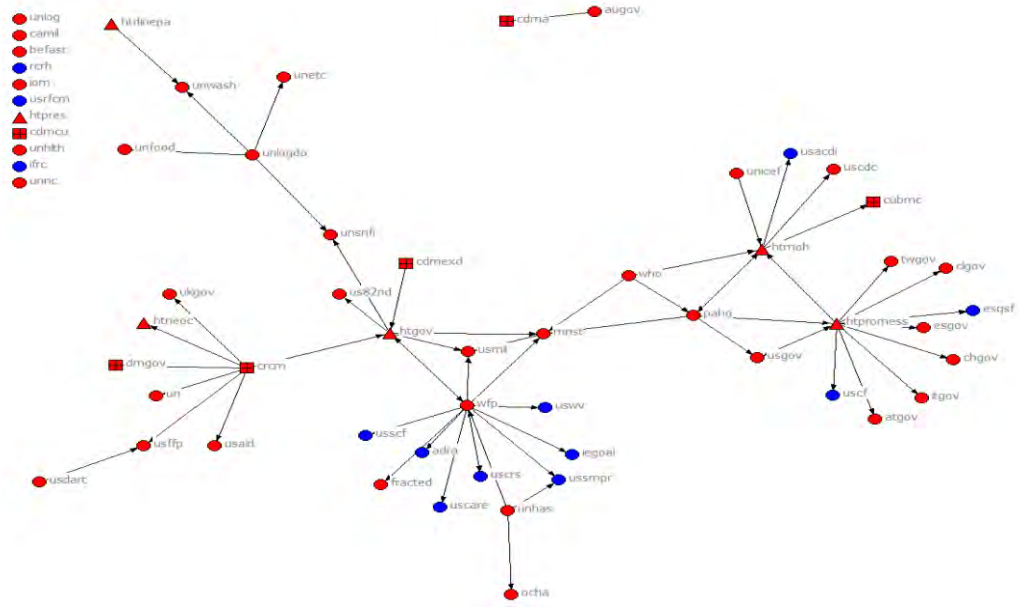

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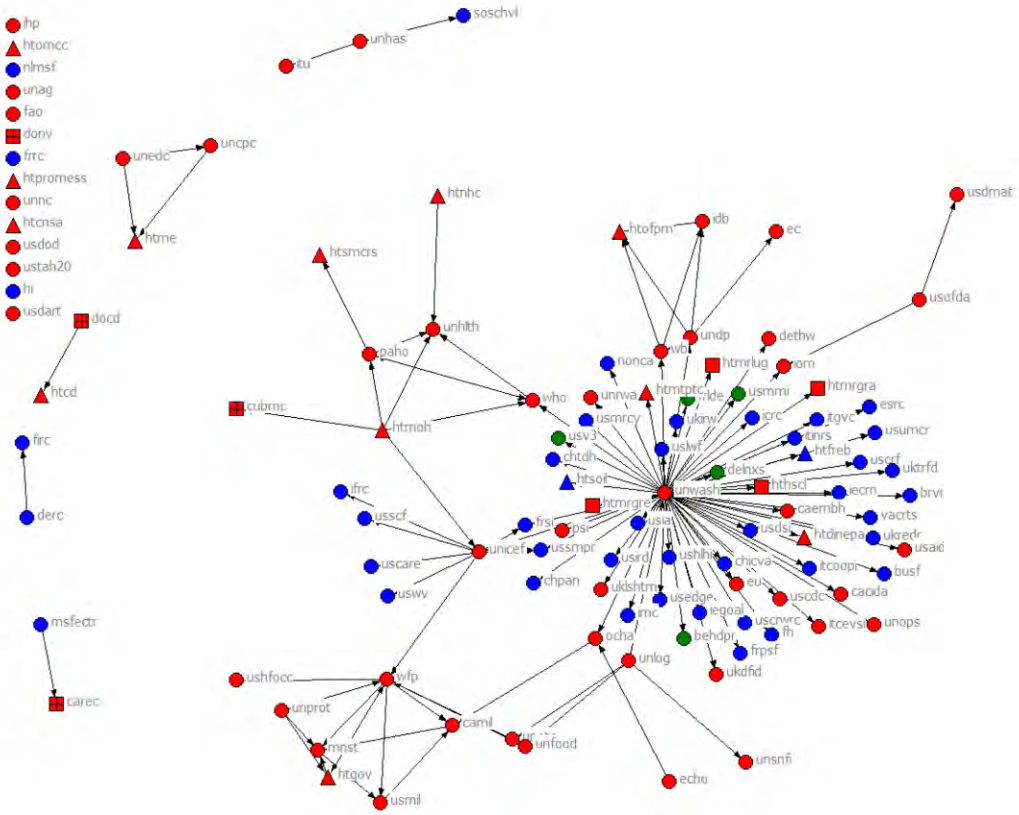

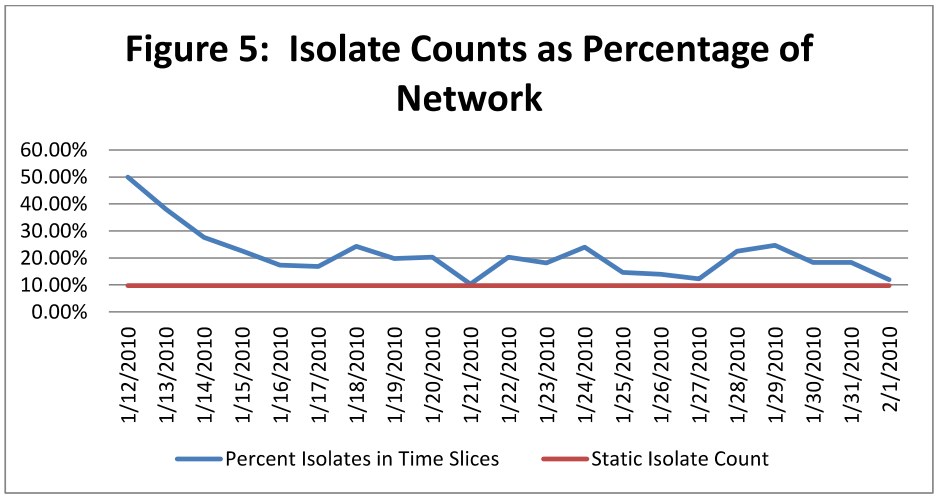

Appendix 3: Complete Organization List (Alphabetical Order by Acronym)

Acronym	Initiating Organization	Acronym	Initiating Organization
aai	Airline Ambassadors International (AAI)	auaaid	Australia Agency for International Development
acaps	Assessment Capacities		
adra	Adventist Development and Relief Agency (ADRA)	augov	Government of Australia
		bbccrif	Caribbean Catastrophe Risk Insurance Facility (CCRIF)
agcb	Antigua Commercial Bank		
aggov	Government of Antigua and Barbuda	bbfcib	First Caribbean International Bank Barbados
agliat	LIAT Airline	bbgov	Government of Barbados
aid	Action Aid	bbofcmo	Office of Chief Medical Officer Barbados
aifrs	Anguilla Fire and Rescue Service	bbofpm	Office of the Prime Minister of Barbados
aigov	Government of Anguilla	bbomh	Office of Minister of Health in Barbados
airc	Red Cross Anguilla	befast	Belgian First Aid & Support Team (B-FAST)
argov	Government of Argentina	begov	Government of Belgium
atgov	Government of Austria	behdpr	Hydropur
atrc	Red Cross Austria	bemsf	Medecins Sans Frontieres (MSF) Belgium

Acronym	Initiating Organization
bmgov	Government of Bermuda
bogov	Government of Bolivia
borc	Red Cross Bolivia
brfh	Brazilian Field Hospital
brgov	Government of Brazil
brmil	Brazilian Army
brvr	Viva Rio
bsgov	Government of Bahamas
busf	Bomberos Unidos sin Fronteras (BUSF)
bzgov	Government of Belize
cacida	Canada International Development Agency (CIDA)
caembh	Embassy of Canada in Haiti
cagov	Government of Canada
cahpi	HOPE International
cama	Medical Ambassador of Canada Association
camdm	Médecins du monde Canada
camil	Canadian Forces
camilmd	Canadian Forces Medical Service
campc	Ministerial Preparatory Conference in Canada
capadess	Health System Development Support Canada (PADESS)
carc	Red Cross Canada
carec	UN PAHO Caribbean Epidemiology Centre (CAREC)
carelic	CARELIC
cbi	Caribbean Development Bank (CBI)
cbiopro	Caribbean Development Bank (CBI) Office of President Regional Operations
cdma	CDEMA (Caribbean Disaster Emergency Management Agency)
cdmcu	CDEMA Coordinating Unit
cdmexd	CDEMA Office of Executive Director
cdmndg	CDEMA Northwestern Donor Group
chfh	Swiss Field Hospital
chgov	Government of Switzerland
chhaid	Swiss Humanitarian Aid
chicva	International Council of Voluntary Agencies (ICVA)
chmsf	Medecins Sans Frontieres (MSF) Switzerland
chpan	ProAct Network
chtdh	Terre des Hommes
cimh	The Caribbean Institute of Meteorology and Hydrology (CIMH)
clgov	Government of Chile
cnisrt	China International Search and Rescue Team
cnmept	Chinese Medical and Epidemic Prevention Team
coarc	ARC Cartagena
cofh	Colombian Field Hospital
cogov	Government of Colombia
corc	Red Cross Colombia
cosar	Columbia Search and Rescue Team
crcm	CARICOM (Caribbean Community) Secretariat
crcmcdru	CARICOM Disaster Relief Unit (CDRU)
crcmhm	CARICOM Bureau of Health Ministers (Guyana,Barbados, Grenada)
crcmiacs	CARICOM Implementation Agency for Crime and Security
crcmoc	CARICOM Office of Chairman
crcmosg	CARICOM Office of Secretary General
crcmrpjm	CARICOM Sub Regional Focal Point Jamaica
crcmrss	CARICOM Regional Security System (RSS)
crcmrssrc	CARICOM RSS Office of Regional Coordinator
crcmtap	CARICOM Tactical Advance Party (TAP)
cubmc	Brigada Medica Cubana
cucorp	Cuban Humanitarian Corporation
cugov	Government of Cuba
czpin	People in Need
decoop	German Federal Ministry for Economic Cooperation and Development
dedhl	DHL
dedhlbb	DHL Barbados
dedhldrt	DHL Disaster Response Team (DRT)
degov	Government of Germany
delnxs	LANXESS
derc	Red Cross Germany
destcc	German Society for Technical Cooperation
dethw	Bundesanstalt Technisches Hilfswerk (THW)
dkema	Danish Emergency Menagment Agency
dkgov	Government of Denmark
dmgov	Government of Dominica
doadm	Aerodom (Airport management authorities DR)
dozzua	Dominican Republic Town of Azua
dobar	Dominican Republic Town of Barahona
dobl	Dominican Republic National Blood Program
dobsh	Dominican Republic Buen Samaritano Hospital
docd	Dominican Republic Civil Defense
doep	Dominican Republic Town of Elias Piña
dogmh	Dominican Republic General Melenciano Hospital
dogov	Government of the Dominican Republic
dogovorc	Government of Dominican Republic, Office of the Resident Coordinator
dojh	Dominican Republic Jimani Hospital
domoh	Ministry of Health in the Dominican Republic
domts	Dominican Republic Town of las Matas de Farfan
donba	Dominican Republic Town of Neiba, San Juan de la Maguana
donv	Dominican Republic Navy
dorc	Red Cross Dominican Republic
dosdq	Las Americas Airport, Santo Domingo
doshell	Shell, Santo Domingo
dosrt	Dominican Republic Search and Rescue Team
douasd	Universidad Autónoma de Santo Domingo
dozxd	San Isidro Air Base
dpemhq	Office of Disaster Preparedness and Emergency Management (ODPEM) HQ, Jamaica
ec	EC (European Comission)

Acronym	Initiating Organization
echo	EC Humanitarian Aid & Civil Protection (ECHO)
eeerb	Estonian Rescue Board (Päästeamet)
escoop	Spanish Agency for International Development Cooperation (AECID)
esfh	Spanish Field Hospital
esgov	Government of Spain
esmsf	Medecins Sans Frontieres (MSF) Spain
esqsf	Queen Sofia Foundation
esrc	Red Cross Spain
eu	European Union (EU)
fao	UN Food and Agriculture Organization (FAO)
faodg	UN Director General of FAO
fh	Food for the Hungry (FH)
figov	Government of Finland
fimi	Ministry of Interior Finland
firc	Red Cross Finland
fracf	Action Contre la Faim (ACF)
fracted	Agency for Technical Cooperation and Development (ACTED)
frami	Aide Médicale Internationale (AMI)
fratlog	Atlas Logistique
fravf	Agronomes and Veterinaires sans Frontieres
fremb	Embassy of France in Haiti
frfh	French Field Hospital
frgov	Government of France
frlde	Lyonnaise Des Eaux
frmdil	Medecins d'Intervention de Lorraine (MEDILOR)
frmed	French Medical Team
frmsf	Medecins Sans Frontieres (MSF) France
frpciv	La Protection Civile Francaise
frpea	Parole et Action
frpsf	Pompiers Sans Frontiers
frpu	Première Urgences
frr	Radio France
frrc	Red Cross France
frsamu	Service Aide Medicale d'Urgence (SAMU)
frsi	Solidarités International
frtsf	Telecoms Sans Frontiers
frvi	Veolia International
gdgov	Government of Grenada
gdomh	Office of Health Minister Grenada
gret	GRET
grgov	Government of Greece
gygov	Government of Guyana
gyomh	Office of Health Minister Guyana
hhnf	Help Haiti Now Fund
hi	Handicap International
hmfrst	Humanity First
htahph	Association des H pitaux Prives d'Haiti
htapsif	Association pour la Promotion de la Sante Integralede la Famille (APROSIFA)
htcd	Haitian Civil Defense
htcdi	Centre de Diagnostique Integral Haiti (CDI)
htcec	Coordinator for Emergency Committee at SOGIET
htcns	Coalition Nationale des Syndicats de Transporteurs Haïtiens
htcnsa	National Food Security Commission Haiti (CNSA)
htdinepa	Direction Nationale de l'Eau Potable et de l'Assainissement (DINEPA) Haiti
hteaumir	Eau Miracle
htfleo	Foyer L'Escale Orphanage
htfreb	Fondation Rose et Blanc (FREB)
htgcc	Groupe des Citoyens ConcernŽs (CC)
htgov	Government of Haiti
hthbn	Hospital Bernard News
hthch	Hôpital de la Communite Haïtien
hthcv	Hospital Canapé Vert
hthdq	Hospital Diquini
htheg	Hospital Eliazard Germain
hthfc	Hospital Freres Community
hthgn	Hospital Gheskio National HIV/AIDS
hthij	Hospital Isaie Jeanty
hthmn	Hospital Miragoane (Nippes)
hthpx	Hôpital de la Paix
hthscl	Hopital St Croix de Luogane
htiat	International Action Ties (IAT)
htibesr	Haitian Institut du Bien Etre Social et de Recherche
htlab	National Laboratory Haiti
htmarndr	Haitian Ministry of Agriculture, Natural Resources, and Rural Development
htme	Ministry of Education in Haiti
htmhh1	Mission of Hope Haiti One
htmoh	Ministry of Health in Haiti
htmosal	Ministry of Social Affairs and Labor
htmrcar	Mairie de Carrefour
htmrgra	Mairie de Grand Goave
htmrgre	Mairie de Gressier
htmrlug	Mairie de Lúogane
htmrpg	Mairie de Petit Goave
htmrpv	Mairie de Petion-Ville
htmrtab	Mairie de Tabarre
htmtpp	Port-au-Prince Toussaint L'Ouverture International Airport
htmtptc	Ministere des travaux publics transports et communications Haiti (MTPTC)
htncmc	National Commission for the Management of the Crises in Haiti
htneo	National Epidemiology Office at the National Health Laboratory
htneoc	National Emergency Operations Centre (NEOC)
htnhc	Coordination Nationale des Secours du Secteur Santé (National Health Commission) Haiti
htnp	Haiti National Police
htnpbs	National Program of Blood Safety Haiti
htofpm	Office of the Prime Minister of Haiti

Acronym	Initiating Organization
htomcc	Office of Minister of Culture and Communication Haiti
htomini	Office of the Minister of the Interior Haiti
htominsal	Office of the Minister of Social Affairs and Labor Haiti
htoutrch	Haiti Outreach
htpacot	Comite rue Pacot
htphope	Project HOPE Haiti
htplan	PLAN Haiti
htpres	Office of the President of Haiti
htpromess	Central Procurement Agency for Drugs and Medical Supplies (PROMESS)
htrc	Red Cross Haiti
htsfi	Children Voice Foundation (SFI) Comite Local
htsmcrs	Metropolitan Solid Waste Removal Service (SMCRS) Haiti
htsoil	Sustainable Organic Integrated Livelihoods (SOIL)
htstsurin	Comite St Surin
httuwt	Trade Union of Water Tankers
htueh	Haiti University and Educational Hospital (HUEH)
iaea	International Atomic Energy Agency (IAEA)
icrc	International Committee of the Red Cross (ICRC)
idb	InterAmerican Development Bank (IADB)
idfh	Indonesia Field Hospital
idmedt	Indonesian Medical Team
ieaid	Irish Aid
iecrn	Concern
iedgcel	Digicel Group
iegoal	GOAL
ifrc	International Federation of Red Cross and Red Crescent Societies (IFRC)
ihp	International Humanitarian Partnership (IHP)
ilfh	Israel Field Hospital
ilntn	Natan (Israeli Coalition for International Humanitarian Aid)
imc	International Medical Corps
indma	National Disaster Management Authority
inws	Internews
iom	UN International Organization for Migration (IOM)
isgov	Government of Iceland
issrt	Iceland Search and Rescue Team
itcevsi	Cooperazione e Sviluppo Italy (CESVI)
itcivpr	Civil Protection Department of the Italian Government
itcoopi	Cooperazione Internazionale (COOPI)
itgov	Government of Italy
itgvc	Gruppo di Volontariato Civile (GVC)
itinrs	Intersos
itu	UN International Telecommunications Union (ITU)
ituer	UN International Telecommunications Union (ITU) Office of Caribbean Representative
jmcaa	Jamaica Civil Aviation Authority
jmfb	Jamaica Fire Brigade
jmgov	Government of Jamaica
jmlime	LIME Jamaica
jmmil	Jamaica Defence Force
jmodpem	Office of Disaster Preparedness and Emergency Management, Jamaica
jpdef	Japan Self-Defense Force
jpjica	Japan international cooperation agency (JICA)
kngov	Government of St.Kitts and Nevis
knopm	Office of Prime Minister St. Kitts and Nevis
kwagl	Agility
lcgov	Government of St. Lucia
lcnemo	National Emergency Management Organisation (NEMO) St. Lucia, Office of Director
let	Logistic Emergency Team (UPS, TNT, Agility)
lugov	Government of Luxembourg
minustahark	MINUSTAH Argentine Military Hospital
minustahbr	MINUSTAH Brazilian military camp
munst	MINUSTAH (UN Stabilization Mission in Haiti)
mnstccu	MINUSTAH Code and Conduct Unit
munstcmc	MINUSTAH CIMIC Office
mnstcms	MINUSTAH Chief of Mission Support
munsthct	MINUSTAH Humanitarian Country Team
mnsths	MINUSTAH Human Services
munstjtc	MINUSTAH Joint Operations Tasking Center (JOTC)
mnstrc	MINUSTAH Resident Coordinator
munstsrsg	MINUSTAH Special Representative of the Secretary-General (SRSG)
msf	Medecins Sans Frontieres (MSF)
msfectr	Epicentre (MSF)
mxcoop	Mexican Cooperation
mxemb	Embassy of Mexico in Haiti
mxgov	Government of Mexico
mxhsp	El Huasteco Mexican Hospital Ship
nemo	National Emergency Management Organisation (NEMO)
nlgov	Government of the Netherlands
nlmsf	Medecins Sans Frontieres (MSF) Netherland
nodcdep	Directorate for Civil Defense and Emergency Planning of Norway
nonca	Norwegian Church Aid (NCA)
nonrc	Norwegian Refugee Council (NRC)
norc	Red Cross Norway
ocha	UN Office for the Coordination of Humanitarian Affairs (OCHA)
ocm	One Caribbean Media (OCM)
oxfam	Oxfam
paho	UN Pan American Health Orgnaization (PAHO)
pahococwsh	UN PAHO/WHO Emergency Operations Center in Washington
pahood	UN Office of Director of PAHO

Acronym	Initiating Organization
pahordr	UN PAHO/WHO Regional Disaster Response
pardu	Pan American Disaster Response Unit (PARDU)
phdoh	Phillippines Department of Health
planint	PLAN International
plgov	Government of Poland
prgov	Government of Puerto Rico
psi	PSI
ptgov	Government of Portugal
rcern	Red Cross Emergency Response Units
rcrh	Red Cross Referral Hospital
rotary	The Rotary Foundation
rufh	Russian Field Hospital
rugov	Government of Russia
salar	Salvation Army
segov	Government of Sweden
semsb	MSB - Swedish Civil Contingencies Agency, former SRSA
sercsn	Ericsson Response
skgov	Government of Slovakia
sknanb	St. Kitts and Nevis Anguilla National Bank
soschvl	SOS Children's Village
srfd	Fire Department of Suriname
srgov	Government of Suriname
srri	Rudisa International Suriname
sswg	Sanitation Strategic Working Group
tccnc	Commissioner of North Caicos
tcgov	Government of Turks and Caicos Islands
tcndc	National Disaster Coordinator Turks and Caicos
trfh	Turkish Field Hospital
trmrt	Turkish Medical Rescue Team
ttgov	Government of Trinidad and Tobago
twgov	Government of Taiwan
ukba	British Airways
ukbbc	BBC
ukbhcbb	British High Commission in Barbados
ukdfid	Department for International Development (DFID) UK
ukdwr	Disaster Waste Recovery
ukgov	Government of United Kingdom
ukhai	Help Age International
ukirw	Islamic Relief Worldwide (IRW)
uklshtm	London School of Hygiene & Tropical Medicine (LSHTM)
ukmap	Map Action
ukmrlnm	MERLIN (Medical experts on the frontline)
ukoxfam	Oxfam UK
ukredr	RedR International
ukscf	Save the Children UK
uktmi	The Mentor Initiative
ukwfd	TearFund
un	UN (United Nations)

Acronym	Initiating Organization
unag	UN Agriculture Cluster
unaids	UN Joint United Nations Programme on HIV/AIDS (UNAIDS)
unccem	Camp Coordination and Camp Management Cluster
uncerf	UN Central Emergency Response Fund (CERF)
unclulb	UN Clinic, Logbase
uncpc	UN Child Protection Cluster
undac	UN Disaster Assessment and Coordination (UNDAC)
undacsd	UN Disaster Assessment and Coordination (UNDAC) Team-Santo Domingo
undp	UN Development Programme (UNDP)
undpkofs	UN DPKO Department of Field Support
unedc	UN Education Cluster
unemrc	UN Office of the Under-Secretary-General and Emergency Relief Coordinator
unep	UN Environment Programme (UNEP)
unerc	UN Early Recovery Cluster
unetc	UN Emergency Telecommunications Cluster
unetcdo	UN Emergency Telecommunications Cluster DR
unfcdo	UN Food Cluster DR
unfood	UN Food Cluster
unfpa	UN Population Fund (UNFPA)
ungscp	UN IASC Gender Standby Capacity Project
unhac	WHO: Health Action in Crises
unhas	UN Humanitarian Air Service (UNHAS)
unhascat	UN Chief Air Transport Officer at UNHAS
unhbt	UN-HABITAT
unhcdo	UN Health Cluster DR
unhchr	UN High Commissioner for Human Rights
unhcr	UN High Commissioner for Refugees
unhlth	UN Health Cluster
unhrd	UN Humanitarian Response Depots (UNHRD)
unhrdbn	UN Humanitarian Response Depot (UNHRD) Brindisi
unhrddb	UN Humanitarian Response Depot (UNHRD) Dubai
unhrdpan	UN Humanitarian Response Depot (UNHRD) Panama
unhsd	UNHC Sub-group: Disability (amputees, spinal cord injuries)
unhse	UNHC Sub-group: Epidemiology
unhsh	UNHC Sub-group: Hospitals
unhshiv	UNHC Sub-group: HIV treatment and care
unhsmh	UNHC Sub-group: Mental Health and Gender Violence
unhsms	UNHC Sub-group: Medical Supplies
unhspc	UNHC Sub-group: Primary care
unhsrh	UNHC Sub-group: Reproductive health
unicef	UN Children's Fund (UNICEF)
unifem	UN Development Fund for Women (UNIFEM)
uninsrag	UN International Search and Rescue Advisory Group (INSARAG)
unlog	UN Logistic Cluster

Acronym	Initiating Organization
unlogdo	UN Logistic Cluster DR
unloghq	UN Logistics Cluster HQ
unnc	UN Nutrition Cluster
unnchq	UN Nutrition Cluster HQ
unops	UN Office for Project Services (UNOPS)
unosat	UN Operational Satellite Applications Programme (UNOSAT)
unosg	UN Office of the Secretary General
unpoloc	UN Office of the chief of UNPOL
unprot	UN Protection Cluster
unrcdo	UN Office of the Resident Coordinator in the Dominican Republic
unrwa	UN Relief and Works Agency (UNRWA)
unsc	UN Security Council
unsnfi	UN Shelter/Non-Food Items Cluster
unwash	UN WASH Cluster Haiti
unwashco	UN WASH Cluster Colombia
unwashhq	UN WASH Cluster HQ
us82nd	US Army: 82nd Airborne
usacdi	ACDI/VOCA
usadf	American Development Foundation (ADF)
usaid	US Agency for International Development (USAID)
usaidad	US Office of the USAID Administrator
usaiddo	US Agency for International Development (USAID) Office in DR
usamb	US Office of the Ambassador to Haiti
usamrtl	AMURTEL
usamxp	Amazon Expeditions
usast	US Americas Support Team
usbcoz	Community Blood Center of the Ozarks
usbcws	Blood Center of Wisconsin
uscare	Care
uscdc	US Centers for Disease Control and Prevention (CDC)
uscf	Clinton Foundation
uscg	US Coast Guard
uscmc	Crowley Maritime Corporation
uscnn	CNN
uscrf	Christian Relief Fund (CRF)
uscrims	Crimson Shipping Company
uscrs	Catholic Relief Service (CRS)
uscrwrc	Christian Reformed World Relief Committee (CRWRC)
uscvn70	USS Carl Vinson (CVN 70)
usdart	US Disaster Assistance Response Team
usdmat	US Disaster Medical Assistant Team
usdmort	US Disaster Mortuary Operational Response Team
usdod	US Department of Defense
usdsi	Deep Springs International
usedge	Edge Outreach
usembdo	US Embassy in Santo Domingo
usembht	US Embassy in Port-au-Prince
usfaa	US Federal Aviation Authority (FAA)
usfcfd	US Fairfax County Fire Department
usfema	US Federal Emergency Management Agency
usfemaad	US Office of the Federal Emergency Management Agency Administrator
usfewsn	USAID Famine Early Warning Systems Network
usffp	US Food for Peace
usfh	USA Field Hospital
usflm	Functional Literacy Ministry of Haiti (FLM)
usfnt	Food and Nutrition Technical Assistance II Project
usfoht	Friends of Haiti
usgov	Government of the United States
usgs	US Geological Survey
usheh	Health Empowering Humanity
ushf	Hesperian Foundation
ushfocc	Haiti Flight Operations Coordination Centre (HFOCC) Miami
ushhi	Harvard Humanitarian International
ushhrf	USAID Haiti Hurricane Relief Fund
ushhs	US Department of Health and Human Services
ushlhi	Healing Hands International
usia	InterAction
usimsrt	US International Medical Surgical Response Team
usirct	Incident Response Coordination Team
usird	International Relief and Development (IRD)
usiycn	USAID Infant and Young Child Nutrition
usjtf	US Military Joint Task Force
uslacfd	US Los Angeles County Fire Department
uslbs	LifeSource Blood Services
uslha4	USS Nassau (LHA-4)
uslhd5	USS Bataan (LHD-5)
uslvchl	Love A Child
uslwf	Lutheran World Federation (LWF)
usmbc	Memorial Blood Center
usmc	US Marine Corps
usmcc	Mennonite Central Committee
usmche	USAID Market Chain Enhancement Project in Haiti
usmfa	US Miami Fire Agency
usmil	US Military
usmmi	Media Mind
usmrcy	Mercy Corps
usmrluw	MERLIN (Water, Sanitation and Hygiene)
usmsh	Management Sciences for Health (MSH)
usmva	MV Alakai
usmvh	MV Huakai
usmvrbc	Mississippi Valley Regional Blood Center
usnoah	National Organization for the Advancement of Haitians (Noah)
usnv	US Navy
usofda	US Office of Foreign Disaster Assistance (OFDA)
usoss	US Office of Secretary of State
usoti	USAID Office of Transition Initiatives
uspfid	Partners for International Development (PfID)

Acronym	Initiating Organization
usph	Partners in Health
usphope	Project HOPE (Health Opportunities for People Everywhere)
usphs	US Public Health Service (USPHS)
uspres	US Office of the President of the United States
usrc	American Red Cross
usrfcm	American Refugee Committee
usrmt	US Response Management Team
usscf	Save the Children Fund (SCF)
usscient	Church of Scientology Volunteer Ministers
usscom	US Southern Command
ussfi	Children Voice Foundation (SFI)
usspr	Samaritan's Purse
ustah20	USNS Comfort (T-AH 20)
ustak3011	USNS Lummus (T-AK 3011)
ustnt	TNT
usucdrh	US Office of the Unified Coordinator for Disaster Response in Haiti
usufl	University of Florida
usumcr	The United Methodist Committee on Relief (UMCOR)
usups	UPS
ususar	US Urban Search and Rescue Teams
usv3	V3 Companies
uswcc	World Care Centre
uswhdb	OFDA Warehouse-Dubai
uswhmi	US OFDA Warehouse-Miami
uswhpi	OFDA Warehouse-Pisa
uswinner	WINNER (USAID)
uswv	World Vision International
uwi	University of West Indies (UWI)
vacrts	Caritas International
vcgov	Government of St.Vincent and the Grenadines
vegov	Government of Venezuela
vigov	Government of Virigin Islands
washrrt	WASH Rapid Response Team
wb	World Bank
wfp	UN World Food Programme (WFP)
wfpcoo	UN Office of the Chief Operating Officer of the WFP
wfpexd	UN Office of Executive Director of WFP
wfphq	UN World Food Programme (WFP) (HQ)
wfpsd	UN WFP Shipping Division
who	UN World Health Organization (WHO)
whoexb	UN WHO Executive Board
zases	South African Structural Engineer Specialists

APPENDIX C. GLOSSARY OF NETWORK TERMS

Bridge: the individual node that is the sole connection between clusters or nodes within the network. Bridges are often identified by their high betweenness value.

Betweenness: The number of times a node acts as a bridge along the shortest path between two nodes. The node with high betweenness values have larger influence in the sharing of information in a network. This assumes that that information sharing follows the shortest path concept.

Centrality measures can be used to determine the most well connected nodes, and so the most important (or influential) nodes, in a network. It is explained using a variety of

- Degree Centrality: Number of links a node possesses.
- Closeness Centrality: the distance between all pairs of nodes, defined by the length of the shortest path.
- Betweenness Centrality: defines the frequency a specific node acts as a bridge via the shortest path between two other nodes. This measure can define network resilience.
- Eigenvector Centrality: is the measure of closeness, a nodes influence within a network. The measure identifies the more central node within the overall network as opposed to those nodes that are highly connected within sub-clusters.

Closeness: Nodes that have the overall shortest paths between other nodes in a network.

Cluster: a cluster is a collection of actors with dense linkage patterns internally and sparse links externally.

Component: The component to which a node belongs is that set of nodes that can be reached from it by paths running along edges of the graph. In a directed graph a node has both an in-component and an out-component, which are the sets of nodes from which the node can be reached and which can be reached from it.

Degree: The number of edges connected to a node. Note that the degree is not necessarily equal to the number of nodes adjacent to a node, since there may be more

than one edge between any two nodes. In a few recent articles, the degree is referred to as the "connectivity" of a node, but we avoid this usage because the word connectivity already has another meaning in graph theory. A directed graph has both an in-degree and an out-degree for each vertex, which are the numbers of in-coming and out-going edges respectively. The average degree is the average number of ties that each node has and is a measure of density.

Density: is a ratio of edges to the possible number of edges within a network. It defines the degree of connectivity within a network. Range 0–1.0

Diameter: The diameter of a network is the length (in number of edges) of the longest geodesic path between any two vertices. A few authors have also used this term to mean the average geodesic distance in a graph, although strictly the two quantities are quite distinct.

Directed/undirected: An edge is directed if it runs in only one direction (such as a one-way road between two points), and undirected if it runs in both directions. Directed edges, which are sometimes called arcs, can be thought of as sporting arrows indicating their orientation. A graph is directed if all of its edges are directed. An undirected graph can be represented by a directed one having two edges between each pair of connected vertices, one in each direction.

Edge: The line connecting two vertices. Also called a bond (physics), a link (computer science), or a tie (sociology).

Fragmentation: The proportion of all pairs of nodes that are not tied with one another.

Geodesic path: A geodesic path is the shortest path through the network from one vertex to another. Note that there may be and often is more than one geodesic path between two vertices.

Hub: Highly connected nodes within a network.

Isolates: Nodes without connection to other nodes within a network.

Isolate Counts: record how many nodes are observed in the network but which lack any connections to any other nodes and network fragmentation records how many separate pieces there are in the network that are connected within that piece, but not to other pieces (Wasserman and Faust, 1994).

Network centralization measures, including clustering coefficients, average distance, and network density describe the shape and amount of possible connections in the network that are actually observed.

Node: The fundamental unit of a network, also called a site (physics), a node (computer science), or an actor (sociology) or a vertice.

ORA: Widely used network analysis software.

Path Distance: a method to calculate distance form nodes to all others ("far-ness"). This is the sum of the distance of each node to all others within the network. The average path length is calculated by adding the shortest path between all nodes and dividing by the total number of pairs.

Path Length: The total number of edges (ties) in a path from one node (actor) to another.

Size: refers to either the number of nodes or edges within a network.

Social Network: A social structure made up of social actors and a set of links (edges) between the actors signifying some definition of social relation.

Sub-group: measures that allow network partitioning. A c*omponent* is parts of a network with all actors are connected. The nodes can be directly or indirectly linked by at least one tie. By definition, each *isolate* is a separate component. A *giant component* is the largest sub-group within a network.

Weighted Network: In an unweighted network all links and nodes are treated as the same. A weighted network adds dimension to the network topology by assigning a value to attributes such as capacity, influence, frequency.

UCINET is a comprehensive software program for the analysis of social networks. The program contains several network analytic routines (e.g., centrality

measures, dyadic cohesion measures, positional analysis algorithms, and clique), and general statistical and multivariate analysis tools such as multidimensional scaling, correspondence analysis, factor analysis, cluster analysis, and multiple regression (Kapucu et al., 2010) p. 231.

APPENDIX D. ICS 205 INCIDENT RADIO COMMUNICATIONS PLAN

INCIDENT RADIO COMMUNICATIONS PLAN (ICS 205)

1. Incident Name:	2. Date/Time Prepared: Date: Time:	3. Operational Period: Date From: Date To: Time From: Time To:

4. Basic Radio Channel Use:

Zone Grp.	Ch #	Function	Channel Name/Trunked Radio System Talkgroup	Assignment	RX Freq N or W	RX Tone/NAC	TX Freq N or W	TX Tone/NAC	Mode (A, D, or M)	Remarks

5. Special Instructions:

6. Prepared by (Communications Unit Leader): Name: _____ Signature: _____

ICS 205	IAP Page _____	Date/Time: _____

ICS 205
Incident Radio Communications Plan

Purpose. The Incident Radio Communications Plan (ICS 205) provides information on all radio frequency or trunked radio system talkgroup assignments for each operational period. The plan is a summary of information obtained about available radio frequencies or talkgroups and the assignments of those resources by the Communications Unit Leader for use by incident responders. Information from the Incident Radio Communications Plan on frequency or talkgroup assignments is normally placed on the Assignment List (ICS 204).

Preparation. The ICS 205 is prepared by the Communications Unit Leader and given to the Planning Section Chief for inclusion in the Incident Action Plan.

Distribution. The ICS 205 is duplicated and attached to the Incident Objectives (ICS 202) and given to all recipients as part of the Incident Action Plan (IAP). All completed original forms must be given to the Documentation Unit. Information from the ICS 205 is placed on Assignment Lists.

Notes:

- The ICS 205 is used to provide, in one location, information on all radio frequency assignments down to the Division/Group level for each operational period.
- The ICS 205 serves as part of the IAP.

Block Number	Block Title	Instructions
1	**Incident Name**	Enter the name assigned to the incident.
2	**Date/Time Prepared**	Enter date prepared (month/day/year) and time prepared (using the 24-hour clock).
3	**Operational Period** • Date and Time From • Date and Time To	Enter the start date (month/day/year) and time (using the 24-hour clock) and end date and time for the operational period to which the form applies.
4	**Basic Radio Channel Use**	Enter the following information about radio channel use:
	Zone Group	
	Channel Number	Use at the Communications Unit Leader's discretion. Channel Number (Ch #) may equate to the channel number for incident radios that are programmed or cloned for a specific Communications Plan, or it may be used just as a reference line number on the ICS 205 document.
	Function	Enter the Net function each channel or talkgroup will be used for (Command, Tactical, Ground-to-Air, Air-to-Air, Support, Dispatch).
	Channel Name/Trunked Radio System Talkgroup	Enter the nomenclature or commonly used name for the channel or talk group such as the National Interoperability Channels which follow DHS frequency Field Operations Guide (FOG).
	Assignment	Enter the name of the ICS Branch/Division/Group/Section to which this channel/talkgroup will be assigned.
	RX (Receive) Frequency (N or W)	Enter the Receive Frequency (RX Freq) as the mobile or portable subscriber would be programmed using xxx.xxxx out to four decimal places, followed by an "N" designating narrowband or a "W" designating wideband emissions. The name of the specific trunked radio system with which the talkgroup is associated may be entered across all fields on the ICS 205 normally used for conventional channel programming information.
	RX Tone/NAC	Enter the Receive Continuous Tone Coded Squelch System (CTCSS) subaudible tone (RX Tone) or Network Access Code (RX NAC) for the receive frequency as the mobile or portable subscriber would be programmed.

Block Number	Block Title	Instructions
4 (continued)	TX (Transmit) Frequency (N or W)	Enter the Transmit Frequency (TX Freq) as the mobile or portable subscriber would be programmed using xxx.xxxx out to four decimal places, followed by an "N" designating narrowband or a "W" designating wideband emissions.
	TX Tone/NAC	Enter the Transmit Continuous Tone Coded Squelch System (CTCSS) subaudible tone (TX Tone) or Network Access Code (TX NAC) for the transmit frequency as the mobile or portable subscriber would be programmed.
	Mode (A, D, or M)	Enter "A" for analog operation, "D" for digital operation, or "M" for mixed mode operation.
	Remarks	Enter miscellaneous information concerning repeater locations, information concerning patched channels or talkgroups using links or gateways, etc.
5	**Special Instructions**	Enter any special instructions (e.g., using cross-band repeaters, secure-voice, encoders, private line (PL) tones, etc.) or other emergency communications needs). If needed, also include any special instructions for handling an incident within an incident.
6	**Prepared by** (Communications Unit Leader) • Name • Signature • Date/Time	Enter the name and signature of the person preparing the form, typically the Communications Unit Leader. Enter date (month/day/year) and time prepared (24-hour clock).

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APPENDIX E. NATIONAL RESPONSE FRAMEWORK ANNEXES AND INCIDENT COMMAND STRUCTURES 2004, 2008 & 2013.

The National Response Plan—2004

1. Emergency Support Functions
2. NRP ESF #2—Communications (Introduction and Scope)
3. NRP ESF #5—Emergency Management (Introduction and Scope)
4. ESF Coordinator and Primary and Support Agencies
5. NRP Incident Management Structure

The National Response Framework—2008

1. Emergency Support Functions
2. NRP ESF #2—Communications (Introduction and Scope)
3. NRP ESF #5—Emergency Management (Introduction and Scope)
4. NRP Incident Management Structure

The National Response Framework—2013

1. Emergency Support Functions
2. NRP ESF #2—Communications (Introduction and Scope)
3. NRP ESF #5—Emergency Management (Introduction and Scope)
4. NRP Incident Management Structure

Incident Command System Glossary

National Response Plan (2004)—Emergency Support Functions

ESF	Scope
ESF #1 - Transportation	▪ Federal and civil transportation support ▪ Transportation safety ▪ Restoration/recovery of transportation infrastructure ▪ Movement restrictions ▪ Damage and impact assessment
ESF #2 - Communications	▪ Coordination with telecommunications industry ▪ Restoration/repair of telecommunications infrastructure ▪ Protection, restoration, and sustainment of national cyber and information technology resources
ESF #3 - Public Works and Engineering	▪ Infrastructure protection and emergency repair ▪ Infrastructure restoration ▪ Engineering services, construction management ▪ Critical infrastructure liaison
ESF #4 - Firefighting	▪ Firefighting activities on Federal lands ▪ Resource support to rural and urban firefighting operations
ESF #5 - Emergency Management	▪ Coordination of incident management efforts ▪ Issuance of mission assignments ▪ Resource and human capital ▪ Incident action planning ▪ Financial management
ESF #6 - Mass Care, Housing, and Human Services	▪ Mass care ▪ Disaster housing ▪ Human services
ESF #7 - Resource Support	▪ Resource support (facility space, office equipment and supplies, contracting services, etc.)
ESF #8 - Public Health and Medical Services	▪ Public health ▪ Medical ▪ Mental health services ▪ Mortuary services
ESF #9 - Urban Search and Rescue	▪ Life-saving assistance ▪ Urban search and rescue
ESF #10 - Oil and Hazardous Materials Response	▪ Oil and hazardous materials (chemical, biological, radiological, etc.) response ▪ Environmental safety and short- and long-term cleanup
ESF #11 - Agriculture and Natural Resources	▪ Nutrition assistance ▪ Animal and plant disease/pest response ▪ Food safety and security ▪ Natural and cultural resources and historic properties protection and restoration
ESF #12 - Energy	▪ Energy infrastructure assessment, repair, and restoration ▪ Energy industry utilities coordination ▪ Energy forecast
ESF #13 - Public Safety and Security	▪ Facility and resource security ▪ Security planning and technical and resource assistance ▪ Public safety/security support ▪ Support to access, traffic, and crowd control
ESF #14 - Long-Term Community Recovery and Mitigation	▪ Social and economic community impact assessment ▪ Long-term community recovery assistance to States, local governments, and the private sector ▪ Mitigation analysis and program implementation
ESF #15 - External Affairs	▪ Emergency public information and protective action guidance ▪ Media and community relations ▪ Congressional and international affairs ▪ Tribal and insular affairs

Emergency Support Function #2
Communications Annex

Primary Agency:	Department of Homeland Security
Support Agencies:	Department of Agriculture, Forest Service Department of Commerce Department of Defense Department of the Interior Federal Communications Commission General Services Administration

I. Introduction

A. Purpose

Emergency Support Function (ESF) #2—Communications ensures the provision of Federal telecommunications support to Federal, State, and local response efforts following a presidentially declared major disaster, emergency, or extraordinary situation under the Federal Response Plan (FRP). This ESF supplements the provisions of the National Plan for Telecommunications Support in Non-Wartime Emergencies, hereafter referred to as the National Telecommunications Support Plan (NTSP).

B. Scope

ESF #2 coordinates Federal actions to be taken to provide the required national security and emergency preparedness (NS/EP) telecommunications support to Federal, State, and local disaster response elements. This ESF will coordinate the establishment of required temporary NS/EP telecommunications and the restoration of permanent telecommunications. Where appropriate, services may be furnished under provisions of the Telecommunications Service Priority (TSP) system. ESF #2 applies to all Federal

departments and agencies that may require telecommunications services or whose telecommunications assets may be employed during a disaster response.

Emergency Support Function #5 – Emergency Management Annex

ESF Coordinator:

Department of Homeland Security/Emergency Preparedness and Response/Federal Emergency Management Agency

Primary Agency:

Department of Homeland Security/Emergency Preparedness and Response/Federal Emergency Management Agency

Support Agencies:

Department of Agriculture
Department of Commerce
Department of Defense
Department of Education
Department of Energy
Department of Health and Human Services
Department of Homeland Security
Department of Housing and Urban Development
Department of the Interior
Department of Justice
Department of Labor
Department of State
Department of Transportation
Department of the Treasury
Department of Veterans Affairs
American Red Cross
Environmental Protection Agency
Federal Communications Commission
General Services Administration
National Aeronautics and Space Administration
Nuclear Regulatory Commission
Office of Personnel Management
Small Business Administration
Tennessee Valley Authority
U.S. Postal Service

Introduction

Purpose

Emergency Support Function (ESF) #5 – Emergency Management is responsible for supporting overall activities of the Federal Government for domestic incident management. ESF #5 provides the core management and administrative functions in support of the National Response Coordination Center (NRCC), Regional Response Coordination Center (RRCC), and Joint Field Office (JFO) operations.

Scope

ESF #5 serves as the support ESF for all Federal departments and agencies across the spectrum of domestic incident management from prevention to response and recovery. ESF #5 facilitates information flow in the pre-incident prevention phase in order to place assets on alert or pre-position for quick response. During the post-incident response phase, ESF #5 transitions and is responsible for support and planning functions. ESF #5 activities include those functions that are critical to support and facilitate multiagency planning and coordination for operations involving potential and actual Incidents of National Significance. This includes alert and notification, deployment and staffing of Department of Homeland Security (DHS) emergency response teams, incident action planning, coordination of operations, logistics and material, direction and control, information management, facilitation of requests for Federal assistance, resource acquisition and management (to include allocation and tracking), worker safety and health, facilities management, financial management, and other support as required.

Figure 2. Designation of ESF coordinator and primary and support agencies

Agency	Emergency Support Functions														
	#1 - Transportation	#2 - Communications	#3 - Public Works and Engineering	#4 - Firefighting	#5 - Emergency Management	#6 - Mass Care, Housing, and Human Services	#7 - Resource Support	#8 - Public Health and Medical Services	#9 - Urban Search and Rescue	#10 - Oil and Hazardous Materials Response	#11 - Agriculture and Natural Resources	#12 - Energy	#13 - Public Safety and Security	#14 - Long-term Community Recovery and Mitigation	#15 - External Affairs
USDA			S		S	S		S		S	C/P	S		P	S
USDA/FS	S	S	S	C/P	S	S	S	S	S	S			S		
DOC	S	S	S	S	S		S		S	S	S	S	S	P/S	S
DOD	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
DOD/USACE			C/P	S	S	S		S	S	S	S	S	S	S	
ED					S										S
DOE	S		S		S		S	S		S	S	C/P	S	S	S
HHS			S		S	S		C/P	S	S	S			P/S	S
DHS	S	S	S		S	S	S	S	S	S	S	S	C/P/S	S	C
DHS/EPR/FEMA		S	P	S	C/P	C/P			C/P	S				C/P	P
DHS/IAIP/NCS		C/P										S			
DHS/USCG	S		S	S				S	S	P			S		
HUD					S	S								P	S
DOI	S	S	S	S	S	S				S	P	S	S	S	S
DOJ	S				S	S		S	S	S	S		C/P/S		S
DOL			S		S	S	S	S	S	S	S	S		S	S

C = ESF coordinator
P = Primary agency
S = Support agency

Note: Unless a specific component of a department or agency is the ESF coordinator or a primary agency, it is not listed in this chart. Refer to the ESF Annexes for detailed support by each of these departments and agencies.

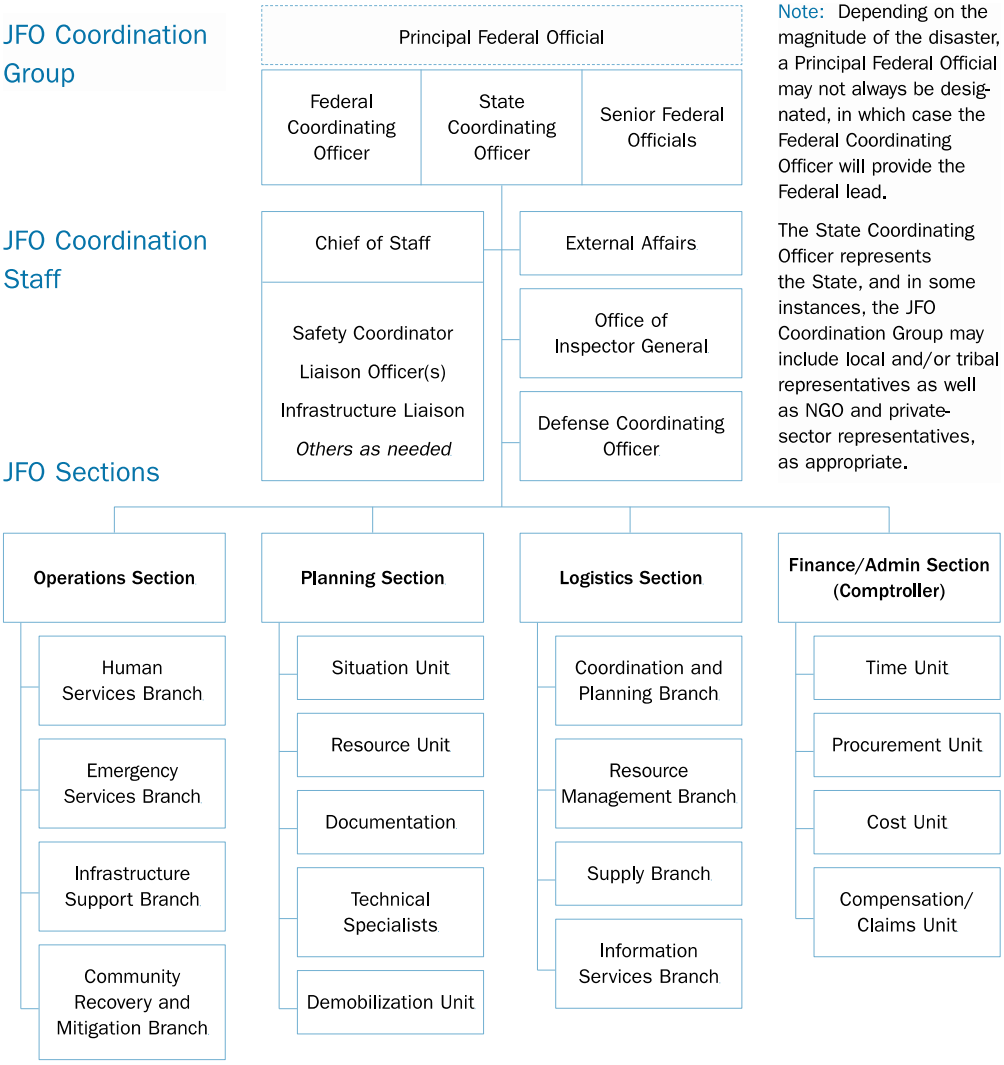
Figure 2. Designation of ESF coordinator and primary and support agencies (Continued)

Agency	Emergency Support Functions														
	#1 - Transportation	#2 - Communications	#3 - Public Works and Engineering	#4 - Firefighting	#5 - Emergency Management	#6 - Mass Care, Housing, and Human Services	#7 - Resource Support	#8 - Public Health and Medical Services	#9 - Urban Search and Rescue	#10 - Oil and Hazardous Materials Response	#11 - Agriculture and Natural Resources	#12 - Energy	#13 - Public Safety and Security	#14 - Long-term Community Recovery and Mitigation	#15 - External Affairs
DOS	S				S			S		S	S	S			S
DOT	C/P		S		S	S	S	S	S	S	S	S		S	S
TREAS					S	S								P	S
VA			S		S	S	S	S					S		S
EPA			S	S	S			S		C/P	S	S	S	S	S
FCC		S			S										S
GSA	S	S	S		S	S	C/P	S		S	S				S
NASA					S		S		S				S		S
NRC			S		S					S		S			S
OPM					S		S								S
SBA					S	S								P	S
SSA						S							S		S
TVA			S		S							S		S	S
USAID								S	S						S
USPS	S				S	S		S			S		S		S
ARC			S		S	P		S			S			S	S

C = ESF coordinator
P = Primary agency
S = Support agency

Note: Unless a specific component of a department or agency is the ESF coordinator or a primary agency, it is not listed in this chart. Refer to the ESF Annexes for detailed support by each of these departments and agencies.

NRP (2004)—Incident Command Structure



Note: Depending on the magnitude of the disaster, a Principal Federal Official may not always be designated, in which case the Federal Coordinating Officer will provide the Federal lead.

The State Coordinating Officer represents the State, and in some instances, the JFO Coordination Group may include local and/or tribal representatives as well as NGO and private-sector representatives, as appropriate.

ESF #2 – Communications **ESF Coordinator: DHS (National Communications System)**
• Coordination with telecommunications and information technology industries • Restoration and repair of telecommunications infrastructure • Protection, restoration, and sustainment of national cyber and information technology resources • Oversight of communications within the Federal incident management and response structures

ESF #5 – Emergency Management **ESF Coordinator: DHS (FEMA)**
• Coordination of incident management and response efforts • Issuance of mission assignments • Resource and human capital • Incident action planning • Financial management

ESF Coordinator:

Department of Homeland Security/National Protection and Programs/Cybersecurity and Communications/National Communications System

Primary Agencies:

Department of Homeland Security/National Protection and Programs/Cybersecurity and Communications/National Communications System
Department of Homeland Security/Federal Emergency Management Agency

Support Agencies:

Department of Agriculture
Department of Commerce
Department of Defense
Department of Homeland Security
Department of the Interior
Federal Communications Commission
General Services Administration

INTRODUCTION

Purpose

Emergency Support Function (ESF) #2 – Communications supports the restoration of the communications infrastructure, facilitates the recovery of systems and applications from cyber attacks, and coordinates Federal communications support to response efforts during incidents requiring a coordinated Federal response (hereafter referred to as "incidents"). This ESF implements the provisions of the Office of Science and Technology Policy (OSTP) National Plan for Telecommunications Support in Non-Wartime Emergencies (NPTS).

ESF #2 also provides communications support to Federal, State, tribal, and local governments and first responders when their systems have been impacted, and provides communications and information technology (IT) support to the Joint Field Office (JFO) and JFO field teams.

With the rapid convergence of communications and IT, the National Communications System (NCS) and the National Cyber Security Division (NCSD) work closely to coordinate the ESF #2 response to cyber incidents. This convergence requires increased synchronization of effort and capabilities between the communications and IT sectors to facilitate ESF #2's ability to respond to all types of incidents.

Scope

ESF #2 coordinates Federal actions to assist industry in restoring the public communications infrastructure and to assist State, tribal, and local governments with emergency communications and restoration of public safety communications systems and first responder networks. ESF #2 supports Federal departments and agencies in procuring and coordinating National Security and Emergency Preparedness (NS/EP) communications services.

ESF #2 provides communications support to the JFO and any JFO field teams.

ESF #2 also addresses cyber security issues that result from or occur in conjunction with incidents. However, for incidents that are primarily cyber in nature, the Cyber Incident Annex is used and ESF #2 supports responses to cyber incidents as directed.

ESF Coordinator:

Department of Homeland Security/Federal Emergency Management Agency

Primary Agency:

Department of Homeland Security/Federal Emergency Management Agency

Support Agencies

Department of Agriculture
Department of Commerce
Department of Defense
Department of Education
Department of Energy
Department of Health and Human Services
Department of Homeland Security
Department of Housing and Urban Development
Department of the Interior
Department of Justice
Department of Labor
Department of State
Department of Transportation
Department of the Treasury
Department of Veterans Affairs
Environmental Protection Agency
Federal Communications Commission
General Services Administration
National Aeronautics and Space Administration
Nuclear Regulatory Commission
Office of Personnel Management
Small Business Administration
Tennessee Valley Authority
U.S. Postal Service
American Red Cross

INTRODUCTION

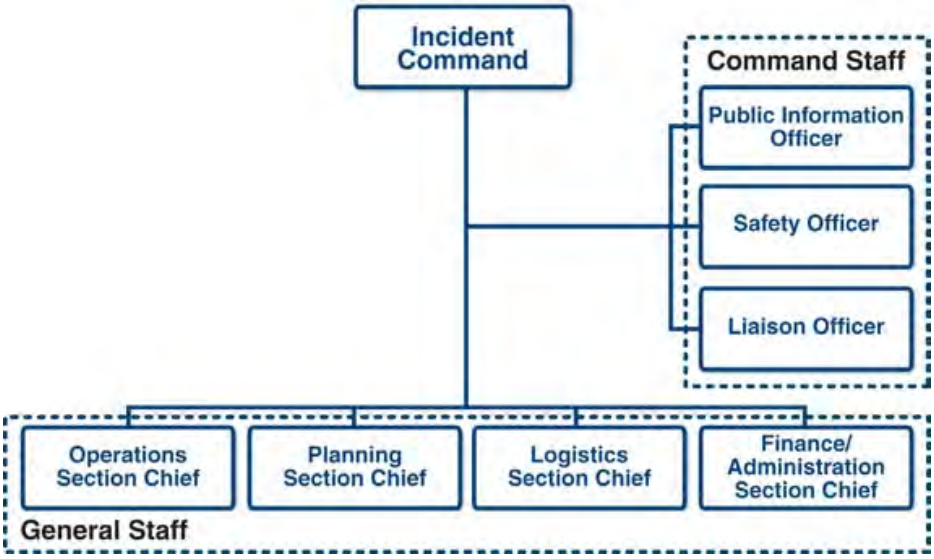
Purpose

ESF #5 – Emergency Management is responsible for supporting overall activities of the Federal Government for domestic incident management. ESF #5 provides the core management and administrative functions in support of National Response Coordination Center (NRCC), Regional Response Coordination Center (RRCC), and Joint Field Office (JFO) operations.

Scope

ESF #5 serves as the coordination ESF for all Federal departments and agencies across the spectrum of domestic incident management from hazard mitigation and preparedness to response and recovery. ESF #5 will identify resources for alert, activation, and subsequent deployment for quick and effective response.

Incident Command Structure (2008, p. 49)



National Response Framework (2013, pp. 32–22)—ESF # 2 & 5

ESF #2—Communications **ESF Coordinator: DHS/National Communications System**
Key Response Core Capability: Operational Communications
Coordinates the reestablishment of the critical communications infrastructure, facilitates the stabilization of systems and applications from cyber attacks, and coordinates communications support to response efforts. Functions include but are not limited to: ▪ Coordination with telecommunications and information technology industries ▪ Reestablishment and repair of telecommunications infrastructure ▪ Protection, reestablishment, and sustainment of national cyber and information technology resources ▪ Oversight of communications within the Federal response structures.

ESF #5—Information and Planning **ESF Coordinator: DHS/FEMA**
Key Response Core Capabilities: Situational Assessment, Planning, Public Information and Warning
Supports and facilitates multiagency planning and coordination for operations involving incidents requiring Federal coordination. Functions include but are not limited to: ▪ Incident action planning ▪ Information collection, analysis, and dissemination.

Emergency Support Function #2 – Communications Annex

ESF Coordinator:

Department of Homeland Security/National Protection and Programs/Cybersecurity and Communications

Primary Agencies:

Department of Homeland Security/National Protection and Programs/Cybersecurity and Communications
Department of Homeland Security/Federal Emergency Management Agency

Support Agencies:

Department of Agriculture
Department of Commerce
Department of Defense
Department of Homeland Security
Department of the Interior
Federal Communications Commission
General Services Administration

INTRODUCTION

Purpose

Emergency Support Function (ESF) #2 – Communications supports the restoration of communications infrastructure, coordinates communications support to response efforts, facilitates the delivery of information to emergency management decision makers, and assists in the stabilization and reestablishment of systems and applications from cyber attacks during incidents.

Scope

ESF #2 acts to meet the telecommunications and essential elements of information needs of local, state, tribal, territorial, insular area, and Federal governmental agencies; nongovernmental organizations; industry essential service providers; other private sector partners; and individuals, families, and households, including individuals with disabilities and others with access and functional needs. The following are responsibilities of ESF #2:

- Provides disaster emergency communications, which consists of the technical means and modes required to provide and maintain operable and interoperable communications in an incident area
- Supports the temporary re-establishment of the basic public safety communications infrastructure and assists in the initial restoration of the commercial telecommunications infrastructure
- Coordinates the provisioning of priority and other telecommunications services at incident support facilities, provides capabilities and services to aid response and short-term recovery operations, and ensures a smooth transition to long-term recovery efforts
- Facilitates the delivery of mission critical information to maintain situational awareness for emergency management decision makers and support elements
- Develops and maintains a communications common operating picture
- Coordinates and deconflicts incident radio frequencies

- Supports cyber incident response as required.

The ESF #2 structure may be used in non-Stafford Act and non-disaster situations where the National Response Framework applies.

RELATIONSHIP TO WHOLE COMMUNITY

This section describes how ESF #2 relates to other elements of the whole community. Basic concepts that apply to all members of the whole community include:

Local, State, Tribal, Territorial, and Insular Area Governments

- Gain situational awareness through reporting that occurs at each level: from local, state, tribal, territorial, insular area, and Federal governmental agencies; nongovernmental organizations; industry essential service providers; other private sector partners; and residents. Information and support requests generally flow from the incident level, though operations and coordination centers, to decision makers. At the same time, decision makers and operations and coordination centers provide accurate, actionable, and relevant information to support incident operations.

- Initiate actions to save and sustain lives, reduce human suffering, and provide additional resources and assistance to response efforts. ESF #2 accomplishes this by providing assistance to stabilize and reestablish critical infrastructure quickly and efficiently, coordinating requests for additional support, identifying and integrating resources and capabilities, and coordinating information flow.

Local authorities are responsible for obtaining required waivers and clearances related to ESF #2 support.

Emergency Support Function #5 – Information And Planning Annex

ESF Coordinator:

Department of Homeland Security/
Federal Emergency Management Agency

Support Agencies:

All Departments and Agencies

Primary Agency:

Department of Homeland Security/
Federal Emergency Management Agency

INTRODUCTION

Purpose

Emergency Support Function (ESF) #5 — Information and Planning collects, analyzes, processes, and disseminates information about a potential or actual incident and conducts planning activities to facilitate the overall activities in providing assistance to the whole community.

Scope

ESF #5 coordinates the development of overall incident situational awareness and the development of Federal plans to manage and support incident activities. Departments and agencies participate in the planning processes coordinated by the planning entity at each incident command or multiagency coordination center.

ESF #5 activities include functions that are critical to support and facilitate multiagency planning and coordination for operations involving incidents requiring Federal coordination. This includes crisis and incident action planning; information collection, analysis, and management; and other support as required.

ESF #5 is organized in accordance with the National Incident Management System (NIMS). ESF #5 supports the general staff functions contained in the NIMS for all the Federal multiagency coordination centers and incident operations (e.g., National Response Coordination Center, Regional Response Coordination Centers, Joint Field Offices).

RELATIONSHIP TO WHOLE COMMUNITY

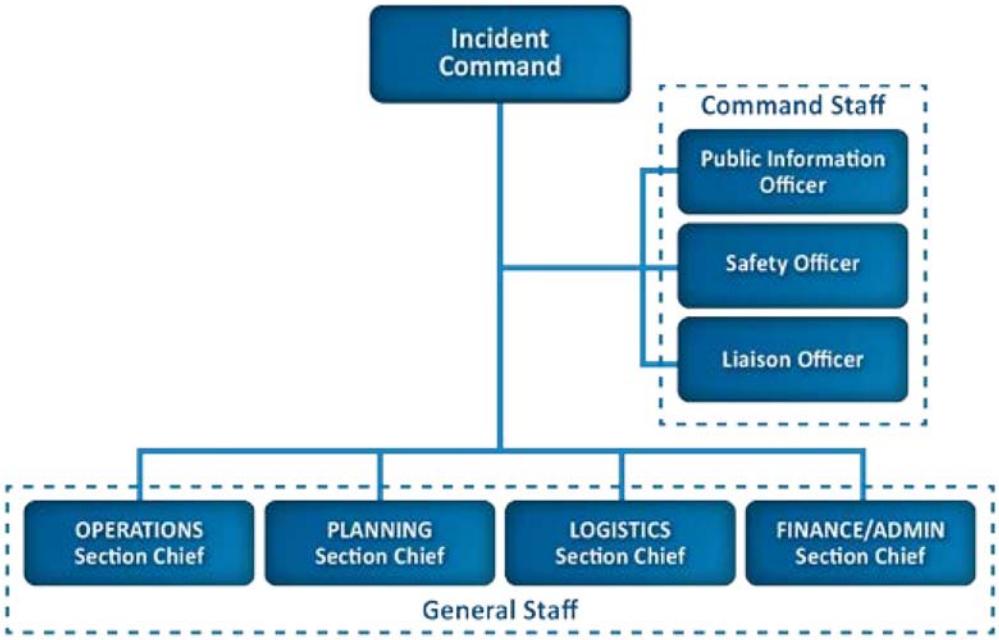
This section describes how ESF #5 relates to other elements of the whole community. Basic concepts that apply to all members of the whole community include:

- Effective incident response activities rely on information and planning systems that provide a common operating picture to all members of the whole community engaged in a response
- Information needs should be defined by the jurisdiction/organization. These needs are often met at the local, state, tribal, territorial, insular area, and Federal levels, in concert with nongovernmental organizations (NGOs) and the private sector, and primarily through preparedness organizations

- Procedures and protocols for the release of warnings, incident notifications, public communications, and other critical information are disseminated through a defined combination of networks used by emergency operations centers. Notifications are made to the appropriate jurisdictional levels and to NGOs and the private sector through defined mechanisms specified in emergency operations plans and incident action plans

- Appropriate auxiliary aids and services are used to effectively communicate information, warnings, notifications, and other critical information for individuals with disabilities and others with access and functional needs.

Incident Command Structure (2013 pg. 38)



ICS Glossary

Source—FEMA Sample Incident Command System (ICS) Organization Chart, accessed 9/9/2014, training.fema.gov/emiweb/is/icsresource/assets/icsorganization.pdf

Command Staff: The Command Staff consists of the Public Information Officer, Safety Officer, and Liaison Officer. They report directly to the Incident Commander.

Section: The organization level having functional responsibility for primary segments of incident management (Operations, Planning, Logistics, Finance/Administration). The Section level is organizationally between Branch and Incident Commander.

Branch: That organizational level having functional, geographical, or jurisdictional responsibility for major parts of the incident operations. The Branch level is organizationally between Section and Division/Group in the Operations Section, and between Section and Units in the Logistics Section. Branches are identified by the use of Roman Numerals, by function, or by jurisdictional name.

Division: That organizational level having responsibility for operations within a defined geographic area. The Division level is organizationally between the Strike Team and the Branch.

Group: Groups are established to divide the incident into functional areas of operation. Groups are located between Branches (when activated) and Resources in the Operations Section.

Unit: That organization element having functional responsibility for a specific incident planning, logistics, or finance/administration activity.

Task Force: A group of resources with common communications and a leader that may be pre- established and sent to an incident, or formed at an incident.

Strike Team: Specified combinations of the same kind and type of resources, with common communications and a leader.

Single Resource: An individual piece of equipment and its personnel complement, or an established crew or team of individuals with an identified work supervisor that can be used on an incident.

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